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THE POTOMAC FORMATION.

BY

LESTER FRANK WARD.

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INTRODUCTION.

The name "Potomac formation" was first used by Mr. W J McGee in 1885.[1] This designation was intended to cover only certain deposits in the States of Virginia and Maryland belonging to the Coastal Plain and lying upon the crystalline rocks of the Piedmont region. It is the same that had been already at that time the subject of somewhat prolonged investigation by Prof. William M. Fontaine, who discovered in it a rich fossil flora and obtained the abundant material for his great work on the Flora of the Potomac or Younger Mesozoic of Virginia.[2] Long prior to this Prof. W. B. Rogers had distinguished this formation in Virginia from the one on the west, to which the Richmond coal field and the Red Sandstones belong. The latter of these formations he supposed to be Jurassic and referred it to the Lower Oolite, chiefly on the evidence of the fossil plants from the Richmond coal field, which had been examined by Bunbury and were thought by him closely to resemble those of the Oolite of Yorkshire, England. The more eastern formation was called by Rogers the Upper Oolite, but its boundaries were very imperfectly determined. In Maryland the iron-ore clays, which have been so long a valuable commercial resource of the State, were recognized by McGee and Fontaine to form in some sense a prolongation of the Potomac formation, but as the Virginia beds chiefly consist of a coarse sandstone, or loose sand, while those of Maryland consist of a red clay, the latter were regarded as later in their date of deposition, and the Potomac formation was therefore divided into a "lower sandstone member" and an "upper clay member."

I began my investigations into the geology and paleontology of the Potomac formation in the year 1885 by joining a reconnaissance made by Messrs. McGee and Fontaine, in which a large portion of the area included in this formation, extending from Baltimore, Md., to Weldon, N. C., was passed over and subjected to somewhat careful study. My

[1] Report of the Health Officer of the District of Columbia for the year ending June 30, 1885, Washington, 1886, p. 20.

[2] Monographs of the U. S. Geological Survey, Vol. XV, Washington, 1889, text and plates.

interest was then chiefly in the fossil plants, as it was also in the year 1886, when, in company with Professors Fontaine and F. H. Knowlton, a collecting tour was made in a steam launch along the bluffs of the Potomac and James rivers, during which large additions were made to the collections of fossil plants. I did not commence the serious study of the stratigraphical relations of these plant beds, and of the rocks in general which make up the formation, until the spring of 1891, when, having completed the work of correlation, from the standpoint of paleobotany, of all the older plant-bearing deposits of the United States, including the Trias, to which I was obliged to refer the Richmond coal field, now sometimes called the Newark system, I began for the same purpose the study of the next succeeding plant-yielding horizon, viz, the Potomac formation. I very soon discovered that the stratigraphical relations of these beds were so imperfectly known that it was impossible to proceed without first making a thorough investigation of the whole subject from the geological point of view. Being well acquainted with the flora, it was clear to me that it must represent a number of distinct periods separated from one another by long intervals of time. I found that the formation had thus far been treated, with the abovementioned exception of its division into two members, as representing practically one period. This was inconsistent with the paleontological evidence. Knowing that the exposed portion of the formation lay between the crystalline rocks on the west and the series of Cretaceous and Tertiary deposits, chiefly marine, on the east, which latter dip coastward and lie regularly imbricated upon one another, it seemed to me altogether probable that if the Potomac formation possessed distinct members, representing different periods of time, or separated by important erosion planes, these several members would also dip coastward and lie imbricated over one another, so that the exposures along the western or landward margin would represent the earlier periods of deposition, and exposures farther eastward, or coastward, would represent successively later periods of deposition.

I therefore began my stratigraphical studies upon this theory, and have conducted them from this point of view during a period of three years. As I advanced with the work I became more and more firmly convinced of the correctness of this position, and the results at which I have been able to arrive—due in the main, as I feel sure, to the employment of a correct hypothesis—are so important that at the risk of seeming to make unsupported assertions I have felt impelled to embody the more general of them in the present paper, in which it will be obviously impossible to give the detailed evidence which has led me to the conclusions stated.

In order, however, that it may appear that these conclusions are based upon actual observations, it seems necessary to give a brief review of these observations. They have not been confined to the States of Virginia and Maryland, but have been conducted upon the

more general theory that the formation which was first laid down upon the ancient floor could not in the nature of things be thus limited, but must have been, originally at least, coextensive with the Coastal Plain, not only on the eastern flank of the continental uplift, but also entirely around its southern border. Though it was not to be expected that it would be found at all points, it was to be expected that it would be found at a sufficient number of points to make it possible to trace it throughout the greater part of its extent.

Involved in this hypothesis was the assumption of the continuance of the formation northeastward through the States of Delaware, Pennsylvania, and New Jersey to the Raritan or the Hudson, and the only homologue in those States seemed to be the Plastic Clays of which the reports of the State geologist of New Jersey have given such an exhaustive account. As it was evident at the outset that the red clays of Delaware were simply a continuation of those of Maryland, the conclusion could not be resisted that those of New Jersey were a still further continuation of the same. The Amboy Clays, so called, had already been carefully studied by Dr. J. S. Newberry from the point of view of the fossil flora, and as early as 1884 he had brought to Washington and permitted me to examine a set of plates illustrating this flora. At the time I commenced my investigations Dr. Newberry's Monograph of the Flora of the Amboy Clays was far advanced, and little more was done upon it before his death in 1892. From considerations of this kind I was led to suspect that this formation might have a still greater northeastern extension, and in 1889 I commenced a systematic investigation of this question by an expedition, with a view to making collections, on Marthas Vineyard. Mr. David White accompanied this expedition, and after a somewhat careful examination of the entire island, as well as of the still more northeastern islands of Tuckernuck, Muskeget, and Nantucket, we finally settled down to a thorough study of the west end of Marthas Vineyard (Gay Head, Nashaquitsa, etc.) in search of plant remains, a very few of which had previously been found by Hitchcock and others. The work of collecting I left to Mr. White, who spent the greater part of the season there and succeeded in making a large collection of fossil plants from the variegated clays hitherto supposed to be Tertiary, which proved to consist chiefly of Amboy types, thus conclusively establishing the hypothesis with which we set out. The clays themselves were also discovered on the island of Nantucket, and Mr. White was able to trace them westward to Long Island, where he also made a collection of fossil plants.

In the expedition above mentioned, in which I accompanied Mr. McGee and Professor Fontaine in 1885 through the State of Virginia, the formation was believed to be traced as far south as the Roanoke. Very little is known of it in the States of North Carolina, South Carolina, and Georgia; but in Alabama the Tuscaloosa formation occupies the same stratigraphical position, resting upon the Carboniferous. This

formation nad been, I believe, uniformly regarded as Lower Cretaceous. In 1888 Professor Fontaine made quite an extensive collection of fossil plants from several localities in the vicinity of Tuscaloosa. These were sent to me and I made a careful examination of them. In all but one of these localities the specimens consisted almost exclusively of dicotyledonous leaves, and I was able to identify a number of them with Amboy Clay forms. In one locality, however, there were numerous conifers, and the dicotyledons were of more ancient types. After finishing the examination of these plants I felt under the necessity of visiting these localities and making further observations upon the Tuscaloosa formation. This I did in the spring of 1892, in company with Dr. Eugene A. Smith, State geologist of Alabama. This expedition was highly successful and resulted in large additional collections. We crossed the formation and endeavored to work out, to a limited extent, its internal relations.

I had already made, in the summer of 1891, in company with Prof. R. T. Hill, an expedition to Texas and southwestern Arkansas, for the purpose of studying the Trinity group, which also has the same stratigraphical relations and rests upon the Carboniferous. One important locality for fossil plants was discovered and a good collection was made. These plants correspond quite closely to the most ancient Potomac forms, such as are found on the James River at the Dutch Gap Canal.

With this general grasp of the subject as a whole, in May, 1892, I resumed the detailed study of the formation in Virginia, Maryland, and farther north. In the greater part of this I was assisted by Mr. David White. The general plan adopted was that of crossing the formation at as many instructive points as it was possible to select, for the purpose of describing all variations that were found to take place in passing from its landward to its coastward margin, and making careful sections at these points. Without here entering into the details of this expedition, I may say in brief that the principal sections thus made in their order from south to north, were:

1. Section of the James River from some distance above Richmond to City Point.

2. Section of the Rappahannock River from above Fredericksburg to the Marl mill at the Eocene contact.

3. Section of the Accokeek Creek from near Mountain View to Indian Head.

4. Section across the formation at Mount Vernon and Fort Washington.

5. Section on the Potomac at Washington. (The entire region in the vicinity of Washington has been explored in its minutest details.)

6. Section through a portion of Prince George County, Md., beginning near Mount Pisgah church and terminating at Brightseat.

7. Section along the Patuxent River from above Laurel to Priests Bridge.

8. Section across the belt from its northwestern margin near Annapolis Junction on the Baltimore and Ohio Railroad, to Round Bay on the Severn River.

9. Section along the Patapsco, from Relay to Bodkin Point, at its mouth.

10. Section through the city of Baltimore. (The entire region surrounding the city of Baltimore was exhaustively studied, and numerous local sections were made.)

11. Section along the Chesapeake Bay, on the eastern shore, extending from the Baltimore and Ohio Railroad to Howells Point.

12. Section in the State of Delaware from Newark, through Christiana, to Delaware City.

13. Section along the Schuylkill and Delaware rivers from some distance north of Conshohocken, through the city of Philadelphia, to below New Castle, Del.

14. Section along the Delaware River from the Triassic contact above Trenton to the Fish House above Camden, N. J.

15. Section in the State of New Jersey from Ten Mile Run in the Sand Hills to Jamesburg.

16. Section along the Raritan from New Brunswick to Atlantic Highlands, N. J.

Careful observations were also made on Staten Island and throughout the clay deposits of northern New Jersey.

After completing these investigations and carefully surveying the literature of the whole subject, including the still unpublished report of Professor Fontaine on the Geology of the Potomac Formation in Virginia, there remained a large number of unsolved problems, or at least questions upon which my conclusions were different from those of others who had worked in the same field. In order to bring about, as far as possible, a harmony of opinion on these questions, I requested Professor Fontaine to accompany me to the principal points which would throw light upon them. After acquainting him with the general conclusions at which I had arrived, we proceeded, in July, 1893, to visit these critical points and discuss them together. Our observations were quite extended, including much of the area from Baltimore and the Severn River to the Rappahannock. The result was a complete harmonizing of all differences and a unity of opinion on all the questions that relate to the area covered. I do not, however, desire to hold Professor Fontaine responsible for any of the statements contained in this paper. In a few cases I have detected errors in our joint observations since they were made which require some modification of the views at which we then arrived. For all statements relating to other parts of the formation I am of course alone responsible, but I wish to acknowledge my indebtedness to Mr. David White for many acute suggestions relative to the proper interpretation of facts.

With these preliminaries I may now proceed to set forth the general nature of the Potomac formation as I understand it.

STRATIGRAPHICAL RELATIONS.

The Potomac formation as thus outlined may be divided into six members, or series, sufficiently distinct to be recognized wherever seen, but not sufficiently distinct to be regarded as geological formations in any proper sense of that term. Taken together they constitute one geological unit or succession of deposits, interrupted only temporarily, and often then only locally. These six series in their ascending geological order may be designated as follows: (1) The James River series, (2) the Rappahannock series, (3) the Mount Vernon series, (4) the Aquia Creek series, (5) the Iron Ore series, and (6) the Albirupean series.

I. THE JAMES RIVER SERIES.

This, as its name implies, is well developed on the James River from Richmond to the Dutch Gap Canal, and also on the Appomattox from below Petersburg to near its mouth, but it is not confined to these rivers and may be seen on the west bank of the Potomac at many points between Mount Vernon and Aquia Creek. From this latter position the normal dip brings it up to the surface some 6 miles west, where it may be seen in the ravines and especially in the railroad cuttings. As seen on the James River it consists of a very coarse gray sand, not distinguishable from, and perhaps the same as, that of the series next to be described. This coarse sand contains a great number of clay lenses and clay balls, the latter of various sizes, while the former sometimes take the form of interstratified deposits extending more or less horizontally through the sand, always bearing evidence of having been worn by the action of water, and often making it extremely probable that they have been moved bodily to a greater or less distance before they ultimately came to rest in the places where they are now found. But some of these clay seams, though always isolated, are too much prolonged to justify the belief that this local displacement can have been very great, and it is possible that some of them may have been deposited in depressions in the sandy bottom of the ancient Potomac sea, and have only had their margins more or less eroded without having been locally disturbed. I am, however, disposed to refer the coarse sands of the James and Appomattox rivers to the Rappahannock series, and to confine the James River series to the underlying clay deposits; but as these clays are often actually embedded in the sands, this would require the assumption that they have all been transported and redeposited. For the smaller clay pellets, clay balls, and clay lenses, this assumption is abundantly sustained; but some of the clay lenses are so extended as to form veritable strata, sometimes 100 feet in length and only a few feet in thickness. Still, even these, wherever they can be traced, are always found to be isolated, with their

extremities abruptly worn off, and often possess other evidence of slight local displacement. As the sands themselves contain no fossils, and are always cross-bedded and more or less disturbed, indicating their deposition in rapidly running water, it is impossible to fix their exact stratigraphical position with reference to the clays, and the theory that the latter were deposited first and have been subsequently slightly transported and redeposited seems to conform more closely to the facts than any other. The following diagrammatic section of the left bank of the Dutch Gap Canal, as sketched by me on October 7, 1892, will show the character of these included clays.

It is difficult or impossible to find the absolute base of the formation on the James and Appomattox rivers, and judging from the analogy presented by the exposures along the Potomac, and by the fact that the sands contain so much redeposited clay, the conclusion can scarcely

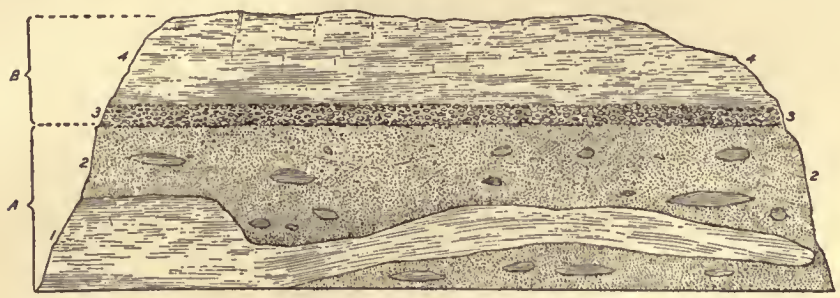

FIG. 1.—Exposure on the north side of the Dutch Gap Canal, James River.

A. Potomac.
1. Clay stratum.
2. Coarse sand and gravel, with clay inclusions.

B. Columbia.
3. Cobble bed.
4. Brick clay.

be escaped that if the base could be reached it would be found to consist of clay, or if not, there would be evidence that it had so consisted, and that the clay had been removed prior to the deposition of the sands.

At Cockpit Point, on the Potomac, on the south side of Gunston Cove, and at numerous other places, heavy beds of sandy clay of a greenish color underlie the sandstones and crop out on the west, as already stated. At one point at least, these clays have been found to contain the characteristic species of the James River series.

The exact nature of these clays has proved difficult to make out. Some of the clay balls included in the sand on the James River, and also in railroad cuttings and other exposures within the city of Richmond, are of a decidedly greenish color, in strong contrast to the greater part of the clay, which is dark, more or less lignite-bearing, or carbonaceous. No vegetable matter has ever been seen in the green clay. The solution of this phenomenon is found in a study of the banks of the Potomac at Cockpit Point, Gunston Cove, and White House Bluff. At the last named of these points the green clays occur in small pellets in

the coarse sand, and even in the lithified rock which abounds there, while the underlying clay bed from which these green clays are derived is chiefly below the surface of the water. But at Gunston Cove, on its south side, such beds of green clay occupy the lowest 20 feet of the bluff, and at Cockpit Point they also rise 20 feet from the water level, and are here overlain by typical freestone of the Rappahannock series holding plant remains.

I at first suspected that the green color might be due to glauconite, although it is of a different shade from that of any true greensand known to me. With this provisional hypothesis I fancied that it might represent deposits in relatively deep water, in which, as the Challenger Reports have shown, glauconite can only be formed. I therefore gave to these beds the name of Bathybian Clays. Specimens of these clays were carefully collected from various points and have been submitted to Prof. J. S. Diller for examination. He finds no glauconite in them, and the green color is due chiefly to chlorite and hornblende. They therefore constitute the true basal clays of the Potomac formation, which seems not to have been deposited in the ocean proper at any point east of the Mississippi River. These clays, moreover, weather out bright pink or purple, sometimes with a violet tinge, and great beds of these superficially colored clays are to be seen at the surface along the Alexandria and Fredericksburg Railroad between Bush Hill and the Occoquan, and along the Telegraph Road from the Occoquan southward. They also occur in the bluffs of the Rappahannock 2 miles above Fredericksburg. In fact, wherever the normal dip brings these lowest beds to the surface they present this aspect. As is well known, the crystalline rocks from which the Potomac derives its materials are more granitic and hornblendic in Virginia than in Maryland, which doubtless accounts for the differences of color which prevail in the basal clays of the Potomac formation in these two States. The prevailing color in Maryland is a delicate lilac, and this seems to penetrate so extensively into the beds that the original color is scarcely known. The plant-yielding material of the James River series is, of course, dark and carbonaceous, or somewhat drab colored, and evidently consists of local beds formed either at the summit of the Bathybian Clays or within them; or even, as it would seem, sometimes formed after the beginning of the sand deposits. In fact, it may be said once for all that in the Potomac formation all clays are arenaceous and all sands argillaceous, and the distinction between the argillaceous sands and the arenaceous clays is being constantly obliterated by transitions in the relative preponderance of the one or the other constituent. Close to the landward border, and apparently underneath the purer clays, there often occur more or less stratified beds of hard pack sand with thin clay layers and quartz pebbles. Indeed, the occurrence of rounded quartz pebbles is a common feature of the lower portions of the formation at all horizons. Taking all these facts into consideration, the James River series may be otherwise designated as the Basal Clays.

II. THE RAPPAHANNOCK SERIES.

I have chosen the term Rappahannock to designate this series, in preference to Fredericksburg or Aquia Creek, for the following reasons: (1) The earliest mention that I have been able to find of the principal rock by which this member is characterized is that of Mr. Latrobe in 1784, who called it the "Rappahannock Freestone," and mentioned the fact that the light-house at Cape Henry was constructed of it. In later times it has been more frequently called the Fredericksburg Freestone, or the Aquia Creek Freestone, from the position of the principal quarries. (2) The term Fredericksburg for this series would lead to confusion, in view of the fact that Prof. R. T. Hill has named one of the members of the Comanche series of Texas the Fredericksburg division, and the time will certainly soon come when the Comanche series of Texas will be correlated with the Potomac formation and the several members will be carefully compared. (3) The objection to the term Aquia Creek series is that it is within the vicinity of Aquia Creek that the most typical deposits of a higher series of the same formation are found, and I have therefore decided to give that name to the member designated as "Brooke" by Professor Fontaine.

Although the fossil plants of the Rappahannock series have chiefly been found in clay pockets, lenses, or thin laminæ, the bulk of the material of which the beds are composed consists of a coarse sand, or frequently sandstone, somewhat massive, white or gray in color. This is the "feldspathic sandstone" of Rogers, for which the modern name is *arkose*, and it has been fully described by Rogers, Fontaine, and McGee. It is full of quartz and other pebbles, more or less worn, and usually contains numerous vegetable impressions, casts, or molds, indicating the presence of trunks and branches of trees. On the Rappahannock, and especially at Alum Rock, near Fredericksburg, this feature is very marked. The plant remains sometimes occur in very thin laminæ in heavy beds of this rock, sometimes in large clay lenses occupying depressions in the rock, but sometimes also at the base of the rock proper in a lignite-bearing clay seam.

The typical Rappahannock freestone has been found only between the Rappahannock Valley and that of Neabsco Creek, and it is within this region, so far as I am aware, that all the quarries are located. On the James and Appomattox rivers the coarse sand so closely resembles that of the Rappahannock that there is scarcely any doubt that it is its exact homologue. The important difference consists in the absence of vegetable remains in the form of stems, trunks, etc., as above described. At Point of Rocks, on the Appomattox, these sands are thoroughly lithified. They have for the most part the same color and general character as the nonlithified sands, but at one point I found them much harder, approaching a quartzite, and of a pinkish color. Nonlithified sands also occur in the Rappahannock region, and in fact transitions in the degree of induration occur at all points.

North of Aquia Creek there is another change which brings this material much more nearly into harmony with that of Point of Rocks, on the Appomattox. Here, as in the James River region, the nonlithified sands predominate, but at White House Bluff for a distance of half a mile they form solid rocks, rising some 30 feet above the surface of the river. Here again the vegetable débris is chiefly wanting. From the Occoquan northward, wherever these sands crop out on the surface at the proper distance from the river, they are always soft and show no signs of solidification, and no hard rock has ever been observed by me north of the Mount Vernon estate. North of Hunting Creek and Cameron Run vast quantities of this sand occur in the hills from the river westward for 4 or 5 miles.

It was long supposed that these sands, which were then regarded as the basal member of the Potomac formation, did not extend across the Potomac River into the District of Columbia and Maryland; but it is now known that they do so extend, and although they are somewhat less pronounced north of the Potomac, they may almost always be found occupying their proper position. Here they are never lithified, and are usually much finer in texture, often forming beds of excellent building sand. The clay which they contain is almost uniformly distributed through the sand, often making it nearly a cream color. It is never stratified, in the proper sense of the word, but is usually cross bedded and shows irregular bedding and lenticular inclusions of slightly varying materials. Lines of worn quartz pebbles are almost always present. In the vicinity of Baltimore, especially to the northeast of the city, these sands are very heavy, and have proved a valuable resource in construction.

One of the most constant features of the Rappahannock sands is the presence of silicified wood, large trunks having been exhumed at various points. One of these, disclosed at the excavation of the new reservoir in Washington, was visible for a length of 40 feet, and its lower portion still remained covered. It is in these sands, too, that the remarkable cycadean trunks, first mentioned by Tyson in 1860, were originally deposited. Most of them have been picked up on the surface or embedded in the overlying Pleistocene deposits, and it was until recently the common belief that they belonged to the Iron Ore Clays. This is now known not to be the case.

In the northern portions of Virginia, in the District of Columbia, and nearly everywhere in Maryland these sands are underlain by a clay deposit of greater or less thickness. This clay is sandy, often passing insensibly into sand, and sometimes not occupying its absolute base—that is to say, passing into sand underneath the clay, and especially into gravel deposits. It is usually highly carbonaceous in constitution, and generally contains large quantities of lignite. It is in these lignitiferous clay beds at the base of the sand that most of the fossil plants of these northern sections have been found. It is the plant remains

that furnish the proof that these clay beds do not belong to the James River series, but do belong to the Rappahannock series. The greater part of the plants in this series have been found in the Rappahannock region and northward to Cockpit Point. By far the larger number were taken from one large clay lens on the bank of the Rappahannock River within the city of Fredericksburg, but the same types have now been found in abundance in the thin clay seams of the Rappahannock freestone at Cockpit Point. Back from the river, on Potomac Run and at various other points, even in that section, these plants occur in the soft lignitic clays underneath the freestone, the same as at more northerly points.

An excellent proof that there is really no stratigraphical distinction between these underlying clays and the sands is found in the fact that the transition from silicified wood to lignite always occurs here, and in at least one case, on the Neabsco Creek in Virginia, a trunk was found passing through from the one into the other, of which the lower portion, embedded in the clay, was lignitized, while the upper portion, embedded in the sand, was silicified.

In some parts of Maryland, especially within the Patapsco drainage, the Rappahannock series assumes a somewhat anomalous character. This is the region in which the Iron Ore Clays attain their maximum development, and the high rounded hills in which the iron pits occur have been supposed to consist entirely of these beds. A recent careful examination of this region has shown that this is not the case, but that the Iron Ore Clays are confined to the upper portion of these hills and overlie very heavy beds of the Rappahannock series. The iron from these beds, in the form of an oxide, has filtered down through the underlying sands to a great distance, staining them with a deep, lively red color, which often makes it difficult for the unpracticed eye to distinguish between the two classes of beds. Here, also, the Rappahannock sands contain clay seams and large masses of clay. The iron infiltration is arrested at these clay seams and thoroughly permeates them, often imparting to them very brilliant hues. These deeply stained clay layers in the Rappahannock sand under the Iron Ore beds are universally known as "paint stone." They often consist of very sandy clay, upon which the effect of the iron has been to form a more or less indurated crust, sometimes a true rock. At places the quantity of this kind of material is very great and forms large masses which have special economic value and are extensively quarried for the manufacture of paint.

At certain points, especially in the valley of Deep Run, a tributary of the Patapsco, these "paint beds" are underlain by very thick deposits of other materials. The strata next below the paint, for a thickness of 20 or 30 feet, are generally of a coarse gravel, scarcely differing in any respect from the true Rappahannock sands as they occur at many points in Virginia. Below these are the lignite beds

already mentioned, only here they attain a very great development, sometimes 40 or 50 feet in thickness. The special peculiarity of these beds is that within them are found embedded immense quantities of nodular ingots of carbonate of iron, the "white ore" of the miners. This ore is greatly superior to the "brown ore" found in the true Iron Ore Clays, and the most extensive and valuable of the iron mines of the State of Maryland are those of the white ore, or "steel ore," as it is sometimes called, in the dark, carbonaceous, lignite-bearing clay of the Rappahannock series, 50 to 75 feet below the base of the Iron Ore Clays.

Recent careful investigations in this and the surrounding regions have shown, with scarcely any possibility of doubt, that the cycad trunks of Maryland, now so celebrated, and of which a very large collection, in addition to those previously known, has recently been made, uniformly come from the upper portion of the paint beds, close to the base of the Iron Ore Clays. A large number of these trunks have been traced with great certainty to this particular horizon, and the exact position of one of them, at least, has been determined. The greater number, however, have been found in the possession of the inhabitants of the district, and it has been necessary to depend to a great extent upon their testimony as to the precise location in which they were found. An exhaustive report upon the whole subject of the cycadean vegetation of the Potomac formation is now being made, but the general conclusion already stated, that the true age of the cycadean trunks is that of the Rappahannock series and not of the Iron Ore Clays, may be safely accepted.

The most northerly point to which I have been able with certainty to trace the Rappahannock series is near Conshohocken, 15 miles northwest of Philadelphia. It occurs here in the form of the lignitic clay, which has a thickness of 8 or 10 feet, lying unconformably upon the blue limestone rock of the Lower Silurian. At Cedar Grove, in this immediate vicinity, there is a large quarry of Trenton marble, upon which Potomac clays, mottled with the various hues characteristic of the Basal Clays, were found resting. At other points in this general region much sand occurs which can not be distinguished from that of the Rappahannock series as shown in Maryland. There can therefore be no doubt that this series once covered these areas, and that we find here a small outlier which has survived the great Schuylkill and Delaware erosion.

III. THE MOUNT VERNON SERIES.

The existence of this series was not discovered until the fall of 1892. It is so inconspicuous that it had been entirely overlooked by all who had previously studied the formation. While it is possible that it may have been originally very general, it seems more probable that it constitutes a somewhat local deposit—at least its homologue has not been

found with certainty north of the Potomac River nor south of the Occoquan. It might therefore be regarded as too unimportant to be treated as a distinct member of the Potomac formation were it not for the fact that it has yielded an entirely unique flora, differing decidedly from that of the Rappahannock series below and of the Aquia Creek series above. Its position between these two series is determined without the slightest shadow of doubt. It consists, so far as known, exclusively of stratified clay of a dark chocolate-brown color, fine in texture and very little sandy, highly charged with carbonaceous matter, so much so as to give it a very low specific gravity, and also to render it quite tenacious. The point at which it was first discovered is about a mile below the Mount Vernon Mansion in the eroded bluff of the Potomac River. More exactly, this spot lies directly underneath the high bluff which is known as Rose's Delight, and only a short distance south of the site of the Fairfax Mansion, all within the former Mount Vernon estate. Here, in chocolate-colored clays, as above described, having a thickness of not more than 4 or 5 feet, and lying immediately upon the partially lithified coarse white sand of the Rappahannock series about 8 feet above the surface of the river, I discovered on October 16, 1892, one of the most interesting plant beds that have ever been found in the Potomac formation. I shall return to this subject when treating of the paleontological evidence. This discovery led me to investigate the occurrence of these clays at other points, and I have been able to trace them along the White House Bluff below, where at one point they have a thickness of some 10 feet, and also yield plant remains of the same types as at Mount Vernon. They are also visible on the south side of Gunston Cove; but what is more important, they have been found to continue westward to where the Rappahannock series comes to the surface; and at various points along the Alexandria and Fredericksburg Railroad, opposite those at which they were found on the Potomac, they occur in precisely the same situation, always lying squarely on the sand, with which they form a strong contrast, and here they are at some points 4 or 5 feet in thickness. Unfortunately no fossil plants could be found at these latter outcrops, but the character of the clays, their constitution, color, etc., as well as their stratigraphical position, leave no doubt that they are the same, and the conclusion is justified that this series overlies the Rappahannock series throughout the entire region from the Occoquan to Little Hunting Creek. There is also evidence, as will be shown presently (see Fig. 2), that stratigraphically, at least, the Mount Vernon series is more closely related to the Rappahannock series below than to the Aquia Creek series above. Faint indications of the occurrence of the homologue of the Mount Vernon series have been observed at a number of points in Maryland, and also on the Rappahannock River, but closer study of this question than has yet been made will be required to establish this.

IV. THE AQUIA CREEK SERIES.

Next in importance to the Rappahannock series, both from a stratigraphical and a paleontological point of view, is undoubtedly to be placed the Aquia Creek series. Professor Fontaine, from a study of these two series of deposits, early conceived the idea of an extensive time hiatus between them. The materials of the latter are so obviously derived to a great extent from those of the former that the hypothesis of an important interruption in the general process of deposition at the close of the Rappahannock period is unavoidable. If there is any line separating what I have called the Potomac formation into two distinct geological units that line must be drawn here. The evidence of an important erosion plane at this level is irresistible. How great the time hiatus was is a difficult matter to settle. The differences in the fossil plants of the two series, as will be seen, are very great. But the force of this is lessened by the fact that the fossil plants of the Mount Vernon series are not only very different from those of the Rappahannock series, but seem to contain types as modern as those of the Aquia

FIG. 2.—Section illustrating the stratigraphical relations of the Mount Vernon Clays. 1. Rappahannock sand. 2. Mount Vernon Clay. 3. Aquia Creek (stratified sand and clays). 4. Franconia gravel, with clay and bowlder inclusions. 5. Decomposed crystalline rock.

Creek series. Quite inconsistent with all this is the further fact that the erosion plane does not occur between the Rappahannock and Mount Vernon series, but between the Mount Vernon and Aquia Creek series. The Mount Vernon Clays adhere snugly to the top of the Rappahannock freestone, and seem to belong to the underlying strata following the contour of the Rappahannock sea bottom in all its undulations, whereas the great unconformity occurs at the base of the Aquia Creek materials. This is clearly shown in the above diagrammatic section, which occurs in a railroad cutting a short distance above Lorton Station (Springman post-office) on the Alexandria and Fredericksburg Railroad, near Pohick Creek.

The materials of the Aquia Creek series, as well as their mode of deposition, are different from those of any of the underlying members of the Potomac formation, although they obviously consist to a large extent of the sands, clays, and gravels of the earlier series. These are redeposited under entirely different conditions, along with other materials from the crystalline rocks on the west. Where the chocolate clays

of the Mount Vernon series are not present, and the Aquia Creek deposits appear to rest directly upon the Rappahannock sands, they may be readily distinguished, primarily by their mode of stratification, being rarely cross bedded and almost always distinctly stratified, usually with thin clay seams between those of the sand; but where no such occur the sands themselves consist of distinct strata of different color and consistency. Secondarily they can usually be distinguished by their color, the sand never possessing the clean white and gray coloring so characteristic of that of the Rappahannock series. They are often stained brown or reddish. They are also much finer and softer, less pure, being intermixed with loam. The grains of sand are not surrounded, as in the Rappahannock series, by a coat of kaolin, but the clay contents occupy the interstices between the grains. In some parts of Maryland this last feature is also present in the Rappahannock sands, and here the main distinction is to be found in the features already described.

The fossil plants occur in the clay seams interstratified between the sands. The Aquia Creek material presents an almost endless variety of forms or phases which can not be here described in detail, but those already mentioned are usually sufficient to enable the practiced eye to distinguish these two deposits at a glance wherever seen. Although the Aquia Creek series is usually deposited unconformably upon the Mount Vernon or Rappahannock, still this is not the principal argument for the fundamental distinction which separates it from these. This argument is rather derived from the obvious character of the former as consisting of materials redeposited from the latter.

The Aquia Creek series was not at first supposed to extend across the Potomac into Maryland. The first fact opposed to this view was the discovery by me of an important plant bed on the left bank of the Potomac within the Fort Foote reservation, at what is known as Rosiers Bluff, yielding characteristic plants of the Aquia Creek series, including many species from the typical localities south of Aquia Creek. This member has now been found at many points in the District of Columbia, especially within the city of Washington, where excavations have been made for the extension of streets through the hills that surround the city on the north. Indications of its occurrence have also been noted at a number of points between Washington and Baltimore, and last summer Professor Fontaine and I demonstrated that a part, at least, of the fossil plants that have been collected in the city of Baltimore at the foot of Federal Hill have come from unquestionable Aquia Creek deposits. Farther northward I have not been able to detect it, but careful observation would no doubt reveal it in that direction.

THE FRANCONIA OVERLAP.

By far the most difficult problem that has been encountered in the study of the Potomac formation is that of accounting for the great amount of disturbed sands, gravels, and cobbles that occupy a wide

belt on its landward margin throughout the greater part of its length. These materials were formerly confounded with the sand and gravel of the Rappahannock series, which were supposed to occupy the base of the formation. Although very different in character, they were supposed to represent the shore-line, and their irregularity of deposition was ascribed to this position. Later, after the discovery of the occurrence of what was first called the Appomattox formation, now known as the Lafayette, the most of this disturbed material was referred to that period, and is still so designated on the geological maps published by the Survey. No attempt has ever been made to draw the line between the supposed Lafayette and the Potomac deposits which so closely resemble it. I was myself at first disposed to regard it all as Lafayette, but certain facts which became more and more obtrusive as the work went on have led me to think that they may in fact belong to the Potomac. They can not, however, be identified with the materials of the Rappahannock series, and if of Potomac age they were deposited toward the close of the Aquia Creek period. In a great number of cases these disturbed materials are found directly overlying the stratified deposits of that series. They are never found far from the landward margin, and always occupy the surface, or if not the present surface, at least the highest place in the Potomac formation.

These materials may be described as consisting principally of sand, gravel, or cobble, the cobblestones usually much worn and varying in size from that of a hen's egg to that of a cannon ball, very irregularly thrown together and never properly stratified, but exhibiting large lenses and short evanescent laminations, first of one material and then of another, usually showing a great local angle of dip, rapidly alternating from anticlinals to synclinals, often exhibiting the "flow and plunge structure," and in general bearing evidence of having been laid down in turbulent and tumultuous waters alternating with periods of quiescence and having many local eddies. Very large bowlders, scarcely at all worn, of quartz, quartzite, gneiss, and granitic rock are frequently seen, sometimes having a diameter of 2 or 3 feet. There are also clay seams, clay lenses, and sometimes lines of very small clay pellets distributed through the mass. Clay is also sometimes found in large amorphous lumps, as if taken up bodily from the underlying strata and deposited without having suffered any appreciable attrition. These are usually pink, but sometimes of other colors. The smaller pebbles, and sometimes stones of considerable size, are often thoroughly rotten, so that while they appear from the general view like the other hard stones, they are found upon examination to be decomposed throughout, and to have the consistency of mere clay balls. In the caving away of banks by natural agencies these stones are frequently divided in half flush with the wall, leaving one-half attached while the other half has fallen below and been crushed to powder in the talus.

The clays were evidently taken up from the basal materials of the Potomac formation, borne to a greater or less distance by rapid currents, and there redeposited. But, as already remarked, they then constituted a superficial deposit, not having the normal dip of the formation but conforming in all respects to the surface of the country. Although they have their origin some distance over on the Aquia Creek material, upon the beveled margin of which they may be seen lying unconformably, they nevertheless spread out far to the westward, overlapping the belt formed by the Rappahannock sands and the James River clays and forming a broad sheet, sometimes miles in width, upon the crystalline rocks.

I am indebted to Mr. David White for the first suggestion of this explanation of these remarkably enigmatic deposits, and if they belong to the Potomac formation at all they can, I believe, be explained only on his theory. When in July last Professor Fontaine and I visited the extensive gravel pits of the Alexandria and Fredericksburg Railroad at Franconia Station, 6 miles southwest of Alexandria, we here found the most complete exhibition of these interesting materials that is known to occur at any one point, and after a thorough discussion of the theory above sketched we decided to name the phenomenon as a whole the Franconia Overlap.

The Franconia Overlap may be seen in all its protean phases at various points between the Rappahannock Valley and the Delaware, occupying the same position on the landward margin of the formation, chiefly in contact with the crystalline rocks, but sometimes traceable over portions of the Rappahannock and Aquia Creek series. It has been the subject of careful study, but any attempt at a detailed description would carry me far beyond the limits of this article.

I should not like to leave this subject without giving expression more decidedly than I have already done to the lingering doubt which I have never been able to overcome as to whether these deposits were really laid down in Potomac time, or whether they may not after all belong to a much later period, for example, that of the Lafayette. There is absolutely no stratigraphical proof of their Potomac age. No formation older than the Columbia (Pleistocene) has ever been found overlying them. Their resemblance to the true Lafayette, so well exhibited on the other side of the belt, is so close that it is often impossible to indicate a distinction. There are, however, some differences, mostly of degree, but often quite important. The following may be said to constitute the entire evidence that the two deposits are of different age:

1. The size of the cobblestones in the Franconia is generally considerably larger than in the Lafayette.

2. The occurrence of large bowlders, as above described, is, I believe, exclusively confined to the Franconia.

3. The clay inclusions of all kinds, as I have described them, belong, so far as I know, exclusively to the Franconia.

4. The upper part of the Aquia Creek series is often much disturbed, and at some exposures, particularly those on Sixteenth street extended, in the city of Washington, the clay masses actually yielding fossil plants, and for this reason referred to the Aquia Creek series, can with difficulty be distinguished from those above them which we are obliged to refer to the Franconia. In other words, a few points are known at which the Aquia Creek series graduates insensibly into the Franconia.

On the other hand, much of the evidence that was at first relied upon to distinguish these formations has broken down entirely. For example, we find in the Lafayette the irregular bedding and disturbed condition the same as we find them in the Franconia, only less marked. The supposition, too, that decayed pebbles, so abundant in the Franconia, necessarily represent a great age and therefore prove its Potomac affinities is now known to be unfounded, and precisely the same conditions may be seen in the typical Lafayette at points where it directly overlies the latest Tertiary deposit, viz, the Chesapeake. Taking everything into consideration, therefore, the only proper scientific attitude as regards the age of the Franconia Overlap seems to be that of a suspension of judgment. But this much, at least, may be said with safety, that whatever its age it is not susceptible to subdivision. It either all belongs to the Potomac or all to the Lafayette, or, at least, all to the same epoch, and it is not possible, as has been done in the geological maps thus far printed, to refer a part to one and a part to another formation.

V. THE IRON ORE SERIES.

This is one of the best known and best recognized members of the Potomac formation, and yet there has been a great amount of both doubt and error in regard to its precise relations to the strata below and above it. It was early supposed to constitute the entire formation in the State of Maryland, and it was this view that led to the adoption by Messrs. McGee and Fontaine of the term "Upper Clay Member." But, as has been seen, further study has shown that the so-called "Lower Sandstone Member" flanks it for its whole length through that State on the northwest. A still more detailed examination has shown that even in the State of Maryland the Aquia Creek series at least is often found occupying its proper place and the Iron Ore Clays proper are superposed more or less conformably upon that series. The most important locality at which these relations can be seen happens to be the one at which the largest number of vegetable remains in the State of Maryland have been found, viz, at the foot of Federal Hill, in the city of Baltimore; and in a fresh clay and sand pit opened by Mr. Weaver on Jackson street which was visited by Professor Fontaine and myself on July 20, 1893, the following section was measured:

	Feet.
8. Typical Iron Ore Clay	20
7. Blue clay without sand	8
6. Blue, lumpy, and sandy clay	2
5. Dark laminated clay	4
4. Paint stone (considerably indurated, brick-red, sandy clay)	6
3. Coarse kaolinic grit	5
2. Paint stone (deep madder-red, somewhat lithified, arenaceous clay)	1
1. Mottled clay with predominating purple hues; depth unknown.	

In No. 5 of this section fossil plants of the Aquia Creek series are abundant, and in No. 6 some vegetable remains were also found. From all that has gone before it is easy to see that this section admits of the following interpretation: No. 1 is the Basal Clay, probably of the James River series. Nos. 2 and 3 represent the Rappahannock series. No. 4 occupies the position, at least, of the Mount Vernon series. Nos. 5 and 6, and probably also No. 7, represent the Aquia Creek series. No. 8 is the Iron Ore series.

The locality is too far from the shore-line for any of the Franconia materials to occur.

The basal portion of the Iron Ore Clays, viz, those parts lying farthest to the landward side of the belt, consists chiefly of a dull-red clay in which is embedded in the form of nuggets of concretionary origin, varying in size from a few inches to a foot or more in diameter, often elliptical or cylindrical, irregular in shape, or much elongated—the brown iron ore of that region. These have frequently been described and are too well known to require further explanation. The series has along this line, forming a belt of 1 to 2 miles in width, a thickness in places of 100 feet.

There is no difficulty in tracing the landward margin of the Iron Ore Clays, or of determining their contact line below. It is often directly underlain by heavy beds of Rappahannock sand without the intervention of the Aquia Creek series, but it differs so greatly from both that there is never any difficulty in distinguishing it. This, however, can not be said for the upper portion of this member, and it has proved a very serious problem to determine where the line should be drawn between the Iron Ore series and the next series above. Certain it is that in passing across the belt, after traveling a certain distance over the Iron Ore Clays, their distinctive features are ultimately lost sight of and a series of different colored clays and white sands at length takes their place. The color of the next succeeding clay beds is usually a bright purple instead of a dull red, and the Iron Ores wholly disappear. Very little more than this can be said with regard to the boundary of the Iron Ore Clays. One may restrict them entirely to the iron-bearing portion, or one may include in them the non-iron-bearing purple clays on the east. But, as will be seen, these latter alternate with the upper white sands throughout the entire extent of the Albirupean series. I shall therefore make no further attempt at such a boundary.

The Iron Ore Clays have not been made out with certainty anywhere in the State of Virginia, all the red clays on the south side of the Potomac being referable to either the James River or the Rappahannock series and being overlain by the Aquia Creek series. But this by no means proves that the Iron Ore series is not present in Virginia. North of Aquia Creek they could hardly occur on account of the proximity of the Potomac River, which cuts away all the eastern portions of the formation. No Iron Ore Clays are visible along the Rappahannock River, although the James River, Rappahannock, and Aquia Creek series lie normally exposed along its banks, and we find the marine Tertiary deposits overlying the last-named series. If the Iron Ore Clays occur at this point they must lie under a great thickness of marine Tertiary a considerable distance farther east. Only by boring at the proper points could the question be settled. On the James River, as has already been seen, even the Rappahannock series rarely or never comes to the surface, and is seen only in the banks of the rivers, overlain by heavy beds of Miocene. At only one point has the Aquia Creek series been made out in this region, viz, at Deep Bottom, 5 miles below the Dutch Gap Canal, which is the most easterly point at which the Potomac formation occurs. If the Iron Ore series is present at this latitude it must be some distance farther east and deeply buried under the later marine deposits. For my own part I am disposed to believe that this is the case, and that the Iron Ore Clays would be found at many places along a line drawn from Fort Washington to City Point. The evidence as to this is in the fact that the Iron Ore Clay does crop out on the eastern shore of the Potomac. At Fort Washington, close to the water's edge, there are many ferruginous nodules and geodic fragments strewn along the shore and partly embedded in red clays, which are indistinguishable from those found in other parts of Maryland where the Iron Ore Clays are distinctly present, and there is reason to believe that these represent that series, which here passes under the alternating clays and sands of the Albirupean series, so distinctly shown in the celebrated exposure at that place.

VI. THE ALBIRUPEAN SERIES.

The name "Albirupean" was first used by Prof. P. R. Uhler in 1888[1] to designate a series of rocks supposed by him to constitute a distinct formation, and especially characterized by the occurrence of large angular blocks of a bright white color, and very hard, found chiefly upon the surface, like erratic bowlders, but sometimes forming considerable ledges along certain rivers that flow into the Chesapeake Bay. The best known of these are the celebrated "White Rocks," which lie in the mouth of the Patapsco River half a mile from its southern shore. These are very large and present four principal masses huddled together

[1] Proc. Am. Phil. Soc., Vol. XXV, Philadelphia, January 6, 1888, p. 42.

and rising some 5 or 6 feet above the surface of the water. Some of them are not white, but of an iron-brown color, and these are also much softer and considerably decomposed. On the north side of the Patapsco, at the extremity of Back River Neck, is another mass of these rocks, and indeed this entire point is made up of a ledge of them. Here the brown colors predominate. This ledge extends some distance up the neck on both sides of Shallow Creek, where it is seen to very good advantage. There is evidence that these rocks are what is left of an outcrop along a nearly north and south line which may extend for many miles in either direction. Near the head of the Magothy River there is another extensive ledge of similar rocks, and in the vicinity of Marley station, on the Annapolis Shortline Railroad, there are quarries of these rocks which were worked many years ago, but have long been abandoned. Another locality at which the white rocks are irregularly strewn over the surface of a considerable area is some 2 miles north of Collington, on the Pope's Creek Railroad, between that place and Bowie station, on the Baltimore and Potomac Railroad. Here they occupy a meadow and wooded depression and do not seem to form a ledge. Rocks of this class also occur in the Patuxent Valley, especially on its left bank several miles above Hicks's Mill. Near Germantown, northeast of Baltimore, there is another area covered by rocks of a similar character, but both from slight differences in the texture of these rocks and also from their position, there is some doubt as to whether they belong to the same system.

The rocks above described form a very small part of the material of the Albirupean series, but they all appear to belong to it and to constitute simply the thoroughly lithified portion of the purest sands contained in that series. The lithification, however, has gone much further than in the Rappahannock freestone, often constituting a true quartzite, and in some specimens it can scarcely be distinguished from some of the Paleozoic rocks, as for example the Medina sandstone.

As was remarked when treating of the Iron Ore series, the exact origin of the Albirupean series is exceedingly vague, as the transition from the Iron Ore Clays to those included in the Albirupean is by insensible gradations. It is possible that it may be ultimately found best to consolidate them into a single member, but if this is done it is the Iron Ore series that will have to be sacrificed, because, though economically so important and popularly so well known, it is geologically of comparatively little significance.

Speaking generally, then, the Albirupean series may be said to consist of beds of alternating clays and sands, the former predominating on the western and the latter on the eastern margin, at least in the State of Maryland. The belt in this State has a breadth of 7 or 8 miles, often more, and in crossing it the principal material seen on the surface is a yellowish sand, intermingled with ferruginous shales and interspersed with larger bowlder-like rocks, sometimes white, but usually reddish brown. Included in these sands there occur large

masses of purple clay, sometimes mottled, often very free from sand and exceedingly tenacious. There also occur dark carbonaceous clays, often plant bearing. Sometimes the clays and sands are laminated and interstratified, constituting what Professor Uhler calls the "alternating clay-sands." The sands, mostly yellowish on the west, often become pure white on the east and furnish the best of building sands. Any of these general phases is likely to occur at any point, but in general the clays predominate in the lower and the sands in the upper portions.

The three most important points at which these various features of the Albirupean series are to be seen are, first, on the Severn River; second, on the south side of the Patapsco River; and third, on the eastern shore of the Chesapeake Bay. In all three of these places all the phases of this series are beautifully revealed, and in comparing these three sections, which are located at considerable distances from one another, it is possible to discover the homologue of any particular feature at all of them. Thus there seems to be one horizon occupying a considerable breadth at which the purple mottled tenacious clays occur in vast quantities. I have denominated this belt the Hawkins Point Clays, from their occurrence at Hawkins Point on the lower Patapsco, where they form an extensive cliff 40 feet in height, with a width along the shore of nearly half a mile toward Swan Creek. Starting with this, we may trace it southward in imagination to where it crops out on the Severn River, 2 miles above Round Bay, and similarly carrying it northward across the Chesapeake we find it presenting precisely the same conditions at Red Point, at the mouth of the Northeast River.

Above this are the alternating clay-sands, some of which present beds of highly carbonaceous clay holding fossil plants, and others a chocolate-colored very sandy clay, also plant bearing. Both these features occur at Round Bay on the Severn River. At Grove Point on the Chesapeake at the mouth of Sassafras River the second of the above-mentioned classes of the plant-bearing deposits has yielded quite a rich flora, the plants being about the same as those collected on the Severn. At Bodkin Point, on the western shore of the Chesapeake just below the mouth of the Patapsco, the same beds have also yielded fossil plants of the same types. In all three of these sections the highest plant beds are within a few feet of the marine Cretaceous formation, and this is seen distinctly overlying the Albirupean sands at the water's edge a short distance below the pavilion at Round Bay.

Some difficulty has been experienced in tracing the formation through the State of Delaware. Few exposures occur in that State, but at Christiana there are heavy beds of red clay underlain by a lignite bed, and there is every reason to suppose that these belong to the Albirupean series. The same conditions were also found at the Red Lion Hotel, 6 miles south of Christiana, and they seem to prevail throughout the level portion of the State, but are mostly covered up by superficial deposits. Below New Castle, however, these clays are to be seen on

the banks of the Delaware, and rise at one point to a height of 6 feet. They undoubtedly underlie the Delaware River, and have here been taken out in large quantities from the bottom of the river for making pottery. These submerged clays are pure white, having escaped oxidation, but turn red on exposure to the air.

The important problem which a consideration of the Albirupean series brings forward is none less than that of the geological position of the Plastic Clays of New Jersey, otherwise called the Raritan and Amboy Clays, which Prof. W. B. Clark has recently proposed to call the Raritan formation. The principal evidence on this point is paleontological, and must therefore be deferred for the present. I may, however, so far anticipate as to say that the flora of Grove Point, Bodkin Point, and Round Bay contains so many of the types of the Amboy Clay flora that it is impossible to doubt that they all belong to practically the same horizon. We are therefore obliged to consider the Amboy Clays as simply a broadening out of the narrow belt which has yielded these forms at these more southerly points, and when we cast our eyes over the map of these regions we see at a glance that this is precisely what we ought to expect on the perfectly rational assumption that these deposits do not abruptly terminate at the Delaware River, but continue their northeastern trend through the State of New Jersey. We have simply to assume that for some reason the clay marls and overlying marine deposits do not extend so far over upon the formation in New Jersey as they do in Delaware and Maryland, and that therefore the exposed belt of these clays is much wider in that State. A careful examination of the entire series of New Jersey clays from their contact with the Newark system on the west to where they disappear under the marls on the east, on both the Delaware and Raritan rivers, has confirmed this hypothesis at all points. That the broad belt of Plastic Clays displayed along the Raritan River from near New Brunswick to Morgan represents a series of deposits and not a mere trough is too obvious to require discussion, and therefore the strata on the western side at Woodbridge, Milltown, and Sayreville represent a lower horizon than those farther east at South Amboy and Morgan, and I may say here that changes in the flora at these several points abundantly confirm this view.

From Morgan, the most easterly point, the formation may be traced northward across Staten Island and the northern shore of Long Island, and it reappears on Marthas Vineyard in the celebrated cliffs of Gay Head. At all of these points the stratigraphical evidence is strongly supported by paleontological evidence. Along this most eastern line a new phase is seen, viz, the occurrence of concretions in the variegated clays, in the form of hard ironstones, which when broken open are often found to contain vegetable remains in an admirable state of preservation. I am therefore disposed to regard these ferruginous, concretionary beds, extending from Staten Island to Marthas Vineyard, as

the very latest phase of the Potomac formation, which I shall call the Island series, although from the similarity in the flora I am disposed to include them, along with the Raritan and Amboy Clays, in the Albirupean series.

The questions will of course be asked, What has become of all the other members of the Potomac formation in New Jersey? Where are the James River, Rappahannock, Aquia Creek, and Iron Ore series? It must be admitted that these are questions difficult to answer. If they were once present it would surely be supposed that some slight traces of them would remain, no matter how great the erosion might have been. Of course there is a possibility that for some reason these beds were never laid down, but this can scarcely be more than a possibility. Assuming that they were once present, how can their absence be accounted for? In the first place, it must be confessed that they have not been diligently and intelligently looked for. If only faint traces of them remain at obscure points, these could only be detected by one who had made the formation a study and who should go on purpose to find them. This has not yet been done. As an illustration of the ease with which such facts may be overlooked, I may again refer to the discovery by Mr. David White and myself, at the point near Conshohocken mentioned above, of just such traces of the old Potomac as may exist in New Jersey. This fact had been entirely overlooked, so far as I have been able to learn, by the Pennsylvania geologists who have so exhaustively studied the geology of that State. We carried Professor Hall's report in our hands as we traveled over this region, and we steered our course by his maps, and yet no Cretaceous is indicated on those maps or mentioned in that report at the point where it was found. Mr. McGee, in traversing this region for the purpose of discoving the Lower Potomac, seems to have found different localities.[1]

On the assumption of the entire absence of the Lower Potomac series in New Jersey, there is one consideration that may, I think, be properly urged in explanation. This is the fact that we have now reached the region of glacial action. It is well known that above the terminal moraine a great amount of loose material that still remains at more southerly points has been planed away by the action of ice. Even the crystalline rocks are decomposed to a considerable depth in the South, and this loose material still covers the harder rocks; but in the North all of this has gone. Such must have also been the fate of all kinds of loose material that lay upon the surface. The Older Potomac strata would have fallen a natural prey to this all-devouring agency, and it may be that the great ice-sheet has succeeded in carrying away the last trace of it over all this region. It will also be seen that this same fact furnishes the explanation of the greater width of the clay belt at these latitudes, for the power that removed the sand and gravel of the Older Potomac was also equal to the removal of a great portion

[1] Cf. Am. Jour. Sci., 3d ser., Vol. XXXV, February, 1888, p. 131.

of the marine Cretaceous and Tertiary deposits which so far overlap these clays at more southern points.

This theory, however, is not sufficient to account for the complete absence of the Lower Potomac at the proper horizon, and we must fall back upon the general assumption which it is necessary to make in studying the Potomac formation, of an oscillation of level at the close of the Rappahannock period, and perhaps also at the close of the Aquia Creek period. As the land rose out of the water the deposits were eroded away, and after it again sank beneath the water the later deposits were laid down upon the new floor and spread out far beyond the margin of the older material. Here in New Jersey we find the clays in direct contact with the Red Sandstones of the Newark system as far west as the Sand Hills and Ten Mile Run. The question is whether farther out in the formation there is any evidence of Older Potomac material underneath the clays. This can be settled only by boring. Fortunately we have some direct evidence on this point in the case of the Jamesburg well, which was completed by Mr. H. F. Walling in 1880 to a depth of 481 feet. A glance at the section published in the annual report of the State geological survey of New Jersey for 1880 (pp. 166–167) shows pretty conclusively that the true Amboy and Raritan Clays were not found below 251 feet. Below this the materials correspond, as nearly as can be judged from borings, to those of the Aquia Creek and Rappahannock series, and possibly they may extend into the James River series. The 60 feet of dark-blue clay ending at 316 feet may represent the Iron Ore series, and the 17 feet of sandstone would seem to belong to the Rappahannock series. The Aquia Creek series may possibly be wanting. The underlying quicksands and clays agree well with much that is known of the James River series.

While speaking of boring, it may be well to mention the remarkable shaft at Fort Monroe sunk by General Humphreys in 1869 to a depth of 907 feet. About 800 feet of this was through the marine deposits, but the last 100 feet or more, judging from the description in Rogers's Geology of the Virginias, page 735, must have been through Potomac material. Professor Fontaine is of the opinion that this was the coarse sand, gravel, and clay of the James River, and it would certainly admit of this interpretation; but considering the great distance (over 50 miles) of Fort Monroe from the most easterly point at which any Potomac has been found, taken in connection with the probability that the upper portions of the formation are represented at most points, it would seem a more reasonable assumption that this last 100 feet consisted of the Albirupean sands and mottled clays, as I have described them.

The limits of this paper will not admit of a discussion of the relations which the facts here presented bear to deposits in other States. I may merely remark, relative to the Tuscaloosa formation, that it seems to present the same relations that are found in New Jersey. The plant-

bearing deposits lying close to the northern or landward margin represent, to all intents and purposes, those of the Raritan and Amboy Clays, and contain, as will be shown, many of the identical types. One locality only, viz, that at Snow's plantation, 9 miles below Tuscaloosa, close to the river surface, indicates a somewhat different flora, representing an earlier date. Some of the types here found occur in the flora of the Aquia Creek series, while others are common to the Amboy Clays. It may be, therefore, that we have here an intermediate flora corresponding in age to the Iron Ore series.

In marked contrast with this is the only florula that has been found in Texas at any horizon that could correspond to that of the Potomac formation, viz, that of the Glen Rose beds of the Trinity division of the Comanche series, which correspond very closely to those of the James River series. In southwestern Arkansas, also, one of the James River species has been determined, and it would seem probable that, generally speaking, the Trinity division corresponds to the James River series.

STRIKE, DIP, AND THICKNESS.

Strike.—The strike of the formation conforms, of course, in a general way to the Atlantic and Gulf coasts. In the Gulf region it is generally east and west, but trends northward in the Mississippi Valley, reaching into Tennessee, and again southward through Arkansas, assuming a more westerly course through Texas. In the Atlantic States it has a direction from northeast to southwest, with, however, many irregularities. Its position is best known in the States of Virginia, Maryland, Delaware, Pennsylvania, New Jersey, and Massachusetts, where it is roughly parallel to the coast. In arriving at the strike in these States, allowance has, however, to be made for the fact already stated, that in Virginia the upper members are covered by overlying marine deposits, while in New Jersey the lower members, if they were ever present, have been eroded away. The real strike is therefore more nearly north and south than a line which should actually follow the margin of the formation as it now exists.

Dip.—Many estimates have been made of the dip in different States, and these vary from 25 to 50 feet to the mile. The former estimate of the State geologist of New Jersey as to the dip of the Plastic Clays was 45 feet to the mile. I have myself made numerous calculations, in most of which it falls considerably below these figures, and 35 to 40 feet would seem to be nearer the truth. Prof. W. B. Clark, in a recent paper, gives the dip of the greensands at between 25 and 30 feet to the mile, which is probably correct; and in fact it should be remembered that in all the deposits of the Coastal Plain the dip diminishes with the age of the deposit.

Thickness.—The thickness of the formation is a much more difficult problem. Estimates have been made by different authors only of certain parts or members separately, as of the Plastic Clays, the Rappahan-

nock series, the Aquia Creek series, the James River series, and the Albirupean series, and not always with a clear conception of their true delimitations. Professor Fontaine has estimated the three principal members in Virginia at 150 feet each. Professor Cook put the thickness of the Plastic Clays at 210 feet in New Jersey, and Mr. Chester at 250 feet in Delaware. Professor Uhler's section of the Albirupean on the Patapsco foots up 500 feet. I am inclined to think that this last is not greatly overestimated. This, it will be remembered, includes the Hawkins Point Clays, which seem to be the equivalent of the Red Clays of Delaware and the lower Plastic Clays of New Jersey.

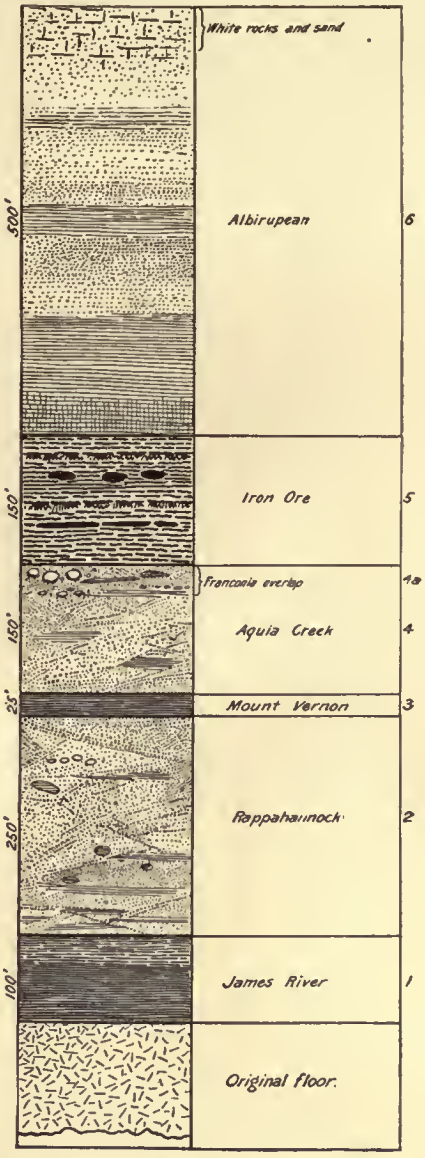

FIG. 3.—Columnar section of the Potomac formation.

In view of the undoubted oscillations of level which have taken place, locally at least, at different horizons within the formation, and the consequent erosion, it becomes impossible to say how much the aggregate of all the deposition would be. It is usually safe to add considerably to any section that may be measured, and the danger is rather of underestimating the thickness than of overestimating it. We may say in general, then, that the James River series probably had a thickness of at least 100 feet, and the Rappahannock series of over 200, perhaps 250, feet. The Mount Vernon series may probably be safely put at 25 feet. The Aquia Creek series is at least 150 feet thick in some places. I do not think that the Iron Ore series, properly restricted, exceeds 150 feet; and I am inclined to accept Professor Uhler's estimate of 500 feet for the thickness of the Albirupean series as I have outlined it. The columnar section, Fig. 3, may therefore represent the thickness of the several members and of the formation as a whole.

Space will not permit a complete illustration of the character of the Potomac formation by means of diagrammatic sections, but the following generalized section (Fig. 4) may serve for all. It assumes what does not, in fact, exist—the occurrence at some point of all the members of the formation at their full thickness, and aims to represent, with of course a greatly exaggerated dip, a complete section across the belt, perpendicular to the strike.

FIG. 4.—General section of the Potomac formation. 1. James River series. 2. Rappahannock series. 3. Mount Vernon series. 4. Aquia Creek series. 4a. Franconia Overlap. 5. Iron Ore series. 6. Albirupean series. A. Pre-Cretaceous (crystalline rocks, Cambrian slate, Carboniferous or Trias). B. Marine Cretaceous (Severn or Matawan). C. Eocene. D. Miocene.

The section, Fig. 5, along an east-northeast and west-southwest line beginning near the village of Occoquan, crossing the Alexandria and Fredericksburg Railroad 1 mile below Lorton station, passing through what is known as White House Bluff on the right bank of the Potomac, and terminating at Fort Washington on its left bank, presents the nearest approach to a complete section of the Potomac formation that I have been able to find. The Franconia Overlap rests upon the crystalline rocks at its western extremity, and is then seen overlying the James River Clays, the Rappahannock sands, and the Aquia Creek series in succession in passing eastward. The Mount Vernon series is well displayed on Pohick Creek and also in the White House Bluff. At this latter point the Basal Clays are seen at tide level and rise in places 5 or 6 feet in the bluff. They are overlain by the Rappahannock sand in its typical indurated state, and over this the Mount Vernon Clays and the Aquia Creek series are displayed in fine sections. It will be observed that the latest of the Tertiary deposits caps the White House Bluff, although it should not appear on the right bank of the Potomac at all. This is not the only case in which the Chesapeake has been found behaving like a superficial deposit and lapping over the beveled edges of older strata. Mr. Darton informs me that its dip is much less than that of the underlying beds. The

green clays of the James River series are seen in the form of lenses and clay balls in the freestone. On account of the westward course of the Potomac at this point the width of the river is here about 5 miles, and when the bluffs at Fort Washington are reached the Iron Ore Clays are found at the base, overlain by a heavy bed, which must be referred to the Albirupean series, and over this both the marine Cretaceous and the marine Tertiary are distinctly seen. The section is about 12 miles long.

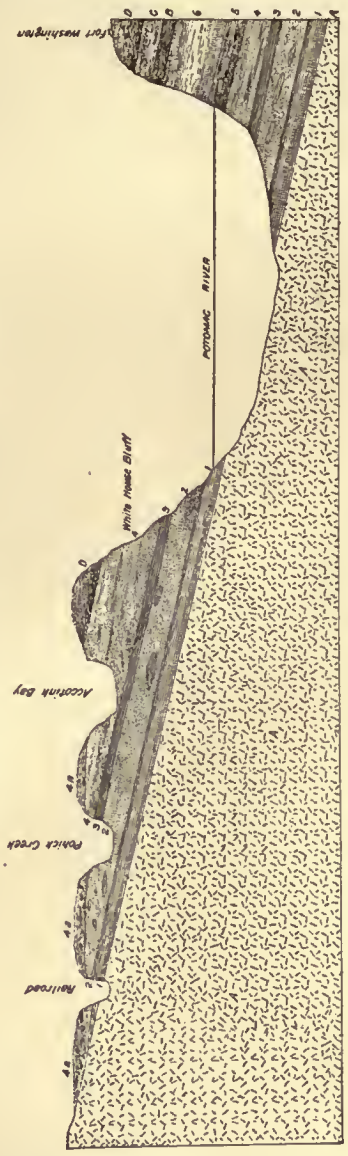

FIG. 5.—Section of the Potomac formation at White House Bluff and Fort Washington. 1. James River series. 2. Rappahannock series. 3. Mount Vernon series. 4. Aquia Creek series. 4a. Franconia Overlap. 5. Iron Ore series. 6. Albirupean series. A. Pre-Cretaceous (Cambrian slate and crystalline rocks). B. Marine Cretaceous (Severn). C. Eocene (Pamunkey). D. Miocene (Chesapeake).

PALEONTOLOGICAL RELATIONS.

The great neglect that the Potomac formation has suffered at the hands of geologists in the past has been chiefly due to the absence of fossil remains. The bulk of the literature relating to the geology of the Coastal Plain is devoted to descriptions of the marine deposits. In treatises of this character it is customary to make a brief mention of the existence of a belt on the west supposed to be of estuarine, fresh, or brackish water origin and destitute of fossils, and travelers crossing this belt, as did Sir Charles Lyell, dismiss the subject with the general remark that from its location it appears to belong to the Mesozoic age and to be either Wealden or Jurassic. The existence of vegetable remains is frequently alluded to, but no idea seems to have been entertained that these could have any value in determining the age of the beds. The few fossil shells that have been found are of brackish or fresh water types, and are of scarcely any importance from the geological point of view. The vertebrate remains are, so far as published, still more meager, but have much greater weight. A brief enumeration of what is known of the animal paleontology may fittingly precede the general discussion from the point of view of fossil plants.

ANIMAL REMAINS.

Invertebrates.—A collection of fossil shells was made many years ago by Professor Cope and turned over to Dr. Isaac Lea, who described them in the Proceedings of the Academy of Natural Sciences of Philadelphia in 1868.[1] They were more fully described and figured, with some additions, by Mr. Robert Whitfield in 1885.[2] These shells came from the banks of the Delaware River a few miles above Camden, N. J. In the same year Mr. T. A. Conrad described two species of Lamellibranchiate shells from the banks of the Raritan,[3] and Mr. Whitfield in the work above cited,[4] has added three others.

All the specimens from the Delaware River belong to the genus Unio, and Mr. Whitfield expresses no opinion as to their geological position. Those from the Raritan Valley belong to the genera Astarte, Corbicula, and Gnathodon, and to a new genus, Ambonicardia. Of these he says:

> All these forms found in the clays are estuary shells, and strongly indicate an estuary formation, which it undoubtedly is. * * * Gnathodon is known to occur in the Cretaceous, but I think not below. * * * Astarte is known in the Jurassic and possibly below, * * * while Corbicula certainly occurs in the Cretaceous and probably below. The new genus, which I have named Ambonicardia, is related to Homomya, and to the smooth forms of Pholadomya, but it will not answer for either. Consequently we get no help of sufficient value to establish the geological horizon of the beds from these molluscan remains, and aside from the evidence furnished by the plant remains we must rely entirely upon the stratigraphical position.[5]

He inclines, however, to the opinion that the beds are of Jurassic age.

Unio shells occur in considerable abundance in one of the typical localities of the Aquia Creek series, near Aquia Creek, where they were collected by my party in 1886. This is a small species, less than an inch in length, and occurs in immediate association with *Sapindopsis variabilis* and various other Aquia Creek species of fossil plants.[6] A specimen apparently of the same species, but somewhat larger, was collected by Mr. William Hunter on May 14, 1893, at the White House Bluff, in the light-colored clay above the Mount Vernon Clay, which is also referable to the Aquia Creek series. Another very similar specimen was collected by Mr. Gilbert Harris at Cockpit Point above the sandstone layer, and therefore probably also in the Aquia Creek series.

The only shell known to have been found at a lower horizon than the Aquia Creek series is a single specimen of the Unio collected by myself

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[1] Vol. XX, pp. 162–164.

[2] Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey; Mon. U. S. Geol. Survey, Vol. IX, pp. 243–252, pls. xxxi–xxxv, Washington, 1885.

[3] Am. Jour. Conchology, Vol. IV, Philadelphia, 1868, p. 279.

[4] Mon. U. S. Geol. Survey, Vol. IX, pp. 22–28.

[5] Ibid., p. 23.

[6] Judging from a remark made by Professor Fontaine in a footnote on page 21 of his Flora of the Potomac Formation (Mon. U. S. Geol. Survey, Vol. XV), I conclude that it was specimens of this species that were submitted to Dr. C. A. White and referred by him to the Crustacean genus Estheria Mr. T. W. Stanton was unable to decide the question from any specimens in the collection that I was able to show him, but both he and Mr. Gilbert Harris expressed the opinion that they were probably immature Unios.

on May 29, 1893, in a bed belonging to the Rappahannock series and yielding abundant remains of *Sphenolepidium Sternbergianum*, *Athrotaxopsis tenuicaulis*, *A. expansa*, and other Older Potomac plants. This specimen is considerably smaller than any of those from the Aquia Creek series. The locality is known as Chinkapin Hollow and is about 2 miles northwest of Alexandria.

The paleontologists all admit that no important conclusions can be drawn from these invertebrate remains as to the age they represent. Their importance is of a negative kind in showing what the plants can not show, that the waters of the Potomac sea were certainly not marine in the paleontological acceptation of that term.

Vertebrates.—In 1859 a portion of a tooth of a saurian reptile found by Mr. Tyson in an iron-ore bed near Bladensburg, Md., was studied by Dr. Christopher Johnston, who proposed the name Astrodon for the animal to which it belonged.[1] This tooth was subsequently submitted to Dr. Joseph Leidy, who described it under the name *Astrodon Johnstoni* in 1864.[2]

Dr. Samuel Lockwood discovered a single dorsal vertebra of a saurian reptile in the clays which underlie the lower Greensand, or Clay Marl (Matawan), near the town of Matawan, Monmouth County, N. J., which was provisionally referred by Professor Cope in 1869 to the genus Plesiosaurus, and named for its discoverer *P. Lockwoodii*.[3] If this specimen was really found below the Clay Marl it must have occurred in the Amboy Clays, and may properly be included in the fauna of the Potomac formation, but of this there seems to be some doubt.

In December, 1887, Mr. J. B. Hatcher made a small collection of bones for Prof. O. C. Marsh from the bottom of an iron-ore pit some 2 miles southwest of Muirkirk, Md., which were described by Professor Marsh in 1888.[4] Five species are here described, all of them new to science, and all but two belonging to two new genera. At the conclusion of this paper Professor Marsh makes the following statement: "The fossils here described and others from the same horizon, seem to prove conclusively that the Potomac formation in its typical localities in Maryland is of Jurassic age and lacustrine origin." Professor Marsh informs me that he has recently obtained a much larger collection of bones from these and similar beds in Maryland, which he has not yet elaborated. It may be said with safety that all these vertebrate remains belong to the Basal Potomac; that is, either to the Rappahannock or the James River series, or both.

[1] Am. Jour. Dental Science, Philadelphia, new series, Vol. IX, July, 1859, p. 341.

[2] Cretaceous Reptiles of the United States; Smithsonian Contributions to Knowledge, No. 192, Vol. XIV, Article 6, May, 1865, p. 102.

[3] Synopsis of the Extinct Batrachia, Reptilia and Aves of North America; Trans. Am. Phil. Soc., new ser., Vol. XIV, Philadelphia, 1871 (see p. 40).

[4] Notice of a New Genus of Sauropoda and other New Dinosaurs from the Potomac Formation; Am. Jour. Sci., 3d ser., Vol. XXXV, No. 205, January, 1888, Appendix, pp. 89-94.

VEGETABLE REMAINS.

It is obvious from the foregoing that, so far, at least, as the correlation of the several members of the Potomac formation is concerned, the animal remains have no value, and it will be necessary to depend upon the fossil plants. Fortunately the flora of the formation is now so well known that it is possible to use it with excellent effect for this purpose. Indeed, without the flora it must be confessed that the subdivision of the Potomac formation would have been practically impossible, although with the aid of the plants it has been possible to show that the stratigraphical distinctions are by no means vague, and are in fact, for the most part, quite distinct. Paleontology, here as elsewhere, has its chief value in setting the limits to stratigraphical determination. Without it the similarity of lithological characters at widely different horizons is so great that it would lead to serious error, but with it these lithological similarities can be interpreted in their true light and such errors avoided. For example, it was natural to suppose, and was in fact supposed by some, that the white rocks at the mouth of the Patapsco and along that portion of the belt, almost the highest exposed, were the same as the Rappahannock freestone in Virginia, but when it is proved paleontologically that the former occupy a very much higher position, there is no difficulty in seeing that the rocks themselves differ widely in the two regions. So also it was natural that the colored clays at the extreme western margin of the formation should be confounded with those of the upper series, and this was very generally done until it was shown by the fossil remains that they must be of a very different character, as they are now clearly seen to be. Again, nothing could have been more reasonable than to have confounded, as was done before the flora was known, the light-colored sands and clays of the Aquia Creek series with those of the Rappahannock series; but now, when paleontology has proved their distinctness, the trained eye of the geologist can instantly recognize and differentiate these two series by their lithological characters alone. And so it is throughout.

The total number of distinct forms that have thus far been recorded as belonging to the Potomac formation proper, that is, east of the Mississippi River, is 737. The greater part of this flora is embodied in two important works: Professor Fontaine's Flora of the Potomac Formation,[1] and Dr. Newberry's Flora of the Amboy Clays, the manuscript and plates for which have recently been submitted for publication as a monograph of the U. S. Geological Survey. In addition to these, however, a number of papers by Dr. Hollick, chiefly relating to the Cretaceous flora of Staten Island and Long Island, have appeared, somewhat increasing the list.

It must not be supposed that this includes the entire present known flora of the Potomac formation. Immense collections have been made

[1] Mon. U. S. Geo. Survey, Vol. XV, 1889.

from a large number of localities in Maryland, Virginia, the District of Columbia, and Alabama which have not yet been elaborated. All that it has been possible to do was to go carefully through them and as far as possible to identify the forms already described in the works mentioned. Even this can not be thoroughly done until these collections are systematically worked up and the specimens drawn and described. But it could be approximately done without this, and no pains have been spared to render these identifications complete, because upon this depends to so large an extent the distribution of the flora among the numerous localities and the several horizons. Many of these identifications are necessarily provisional, and a final elaboration of this material may somewhat alter the general relations as they now stand. Such an elaboration will of course greatly increase the total number of forms, and it is not at all improbable that there have been collected at this date 1,000 species of Potomac plants.

As regards the significance of the Potomac flora as a whole, very little need be said beyond what is already known, viz, that the older forms, those for example that are exclusively confined to the James River and the Rappahannock series, represent an age as great, at least, as the lowest known Cretaceous, and indicate that, so far as comparisons can be made with other parts of the world, the Potomac formation began to be deposited either at the dawn of Cretaceous time or, more probably, a little before the close of the Jurassic age. The occurrence of a few rare and archaic dicotyledonous leaves even in the lowest James River beds would, in the light of all that is known of the origin of that type of plants, indicate that even these beds must come within the Cretaceous system. And yet, from the great abundance and high state of development of this type before the close of the Potomac period, and especially in the Middle Cretaceous—Dakota group of America and Cenomanian of Europe—no one would venture to assert that the subclass Dicotyledones had its absolute origin in the Cretaceous. Upon the whole, I am disposed to consider the Potomac formation as a Cretaceous deposit, but as occupying nearly the whole lower portion of that system; that is, as practically filling the interval from the close of the Jurassic to the base of the Upper Cretaceous, as that is commonly understood. The complete distribution of its fossil plants will, I doubt not, justify this conclusion.

Prior to the beginning of my investigation of this subject it was the common belief of geologists that the Raritan and Amboy Clays of New Jersey belonged to the Upper Cretaceous and were practically equivalent to the Dakota formation, although the earlier writers had generally referred them to the Wealden or Jurassic. The change of opinion on this question was brought about by the discovery of plant remains in the clay pits of New Jersey, a few of which were identified in 1878 by Professor Lesquereux with Dakota forms. This revised opinion was held by Dr. Newberry down to the time of his death, and was shared

by me until 1892, when the evidence was so far in as to compel me to abandon it. Nevertheless, it is better known now than it was then that Dakota forms actually do occur in the Amboy Clays, but it must be supposed that these are such forms as have passed up from the Lower into the Upper Cretaceous. It is also true that a large number of Amboy Clay species are common to these beds and to all of the three Cretaceous deposits of Greenland—the Kome, Atane, and Patoot beds—and there is probably no doubt that the highest of these last belongs to the Upper Cretaceous. While the Atane beds have been referred, even on the authority of their animal remains, to the Cenomanian, there may still be a lingering doubt as to whether they may not be somewhat lower and the practical equivalent of those of New Jersey. The Greenland deposits would thus seem to be a simple extension of the Lower Cretaceous of the Atlantic border.

It can not be denied that a great difference exists between the floras of the Lower and Upper Potomac as thus defined, and the evidence of their unity rests upon the stratigraphy, as showing a general continuity of deposition. The chief difficulty in the way of subdividing this admittedly prolonged epoch is the impossibility of finding any hard and fast lines; and singularly enough, this difficulty is greatest just where it ought to be least, viz, between the Aquia Creek and the Albirupean series, and especially between the Iron Ore series and the beds above. The great geologic break, as already stated, occurs at the close of the Rappahannock series. The existence of the Iron Ore Clays above the Aquia Creek series, and without any decided evidence of erosion, would seem to furnish a sufficiently long period for the really great change that took place in the flora and separates that of the Aquia Creek series from the great dicotyledonous flora of the Raritan and Amboy Clays.

More clearly to express the chronological relations of the several series, I shall designate the James River and Rappahannock series, taken together, as the Basal Potomac, and the four lowest members, viz, the Basal Potomac and the Mount Vernon and Aquia Creek series, taken together, as the Older Potomac. All above the Aquia Creek series may then be treated as the Newer Potomac. The Aquia Creek flora, separated as it is by the great break from the Basal Potomac, and by the nonfossiliferous Iron Ore Clays from the Newer Potomac, may, in harmony with this classification, be called the Middle Potomac.

With these preliminary remarks I shall now proceed to consider the several floras of the Potomac formation, beginning with the lowest, and to discuss their interrelations.

THE JAMES RIVER FLORA.

In treating of the stratigraphical relations of the James River and Rappahannock series it was made sufficiently clear that they constitute practically one prolonged series of deposition, but that the basal

portion is usually more argillaceous and often consists entirely of clay, while the upper portion is almost exclusively sand and gravel, with clay inclusions, the latter sometimes quite extensive and holding the plants, while the arenaceous part is often solidified into rock. It was also shown that at the base of the freestone, or of the sand when not lithified, there usually occurs a lignite bed, the lignite being deposited in clay, and this carbonaceous clay alternates with the sand toward the base of this series, so that there may be sand, and especially gravel, consisting chiefly of rounded vein-quartz, below some or all of the lignite beds. For these reasons this lignite layer was assigned to the Rappahannock series, but in many places this is wanting and, as on the western shore of the Potomac north of Aquia Creek, the freestone rests directly upon heavy clay beds, which are not carbonaceous, have a greenish color, and contain no vegetable remains. There are indications at some places that even these nonfossiliferous clays are underlain by sandy deposits, often ferruginous, and differing essentially from anything else in the formation. Such indications are to be found below Cockpit Point on the Potomac River, and beds of this kind crop out at the surface some miles west along the north and south roads, where they are clearly overlain by the purple clays, which have this color solely through weathering.

It must not, however, be inferred that the distinction between the James River and Rappahannock series is purely stratigraphical. There is an obvious change, though a gradual one, in the character of the flora from the base upward. Even in the case of the common species, occurring in both series and sometimes passing up into the Aquia Creek series, there is either an increase or diminution in their abundance. Such species as *Dioonites Buchianus* (Ett.), Born., and its varieties are extremely abundant in the lower deposit and grow more rare in ascending, while many of the typical Rappahannock species also occur in the James River series, but only rarely; and in general the distinction in the flora of the two may be said to be quantitative rather than qualitative.

The James River series has yielded 152 species of plants, or nearly 21 per cent of the total known flora of the Potomac formation. Of these, 69, or 45 per cent, are confined exclusively to that series, while 73, or over 48 per cent, are common to the James River and Rappahannock series. Of these last, 44, or nearly 29 per cent, are confined to these two series. The remainder of those that are common to the two are found at higher horizons.

THE RAPPAHANNOCK FLORA.

The number of forms described from the Rappahannock series is 221, or 30 per cent of the known flora of the Potomac. This is by far the richest of all the floras of the Older Potomac, but, as has been shown, the thickness of the beds is much greater than that of either the James River or the Aquia Creek series. As already remarked, the prepon-

derance of the plants thus far described were found at one very restricted locality in the city of Fredericksburg, but now a large number of other plant-yielding beds are known, and many specimens have been collected which have not yet been adequately determined. With the exception of a considerable collection from thin clay shales between heavy sandstone layers of the typical freestone at Cockpit Point, all the other collections mentioned are from the lignite beds below the sand. Among the localities of this class, besides the two situated on Potomac Run, treated by Professor Fontaine in his Flora of the Potomac Formation,[1] there may be mentioned two other very promising ones more recently discovered by myself and by no means exhausted as yet. One of these is known as Chinkapin Hollow, and is situated about half a mile east of Fairfax Theological Seminary, and some 2 miles northwest of Alexandria near the Leesburg pike. The other is at the new reservoir in the city of Washington. The plants occur in the bed of the excavation, most of them on the east side, nearly opposite the shaft. A few were found, of quite different types, in a very light brown clay close by the shaft on the west side, and immediately below the position of the huge petrified log of *Cupressinoxylon McGeei*, described by Professor Knowlton.[2]

Of the 221 Rappahannock species, 120, or over 54 per cent, are exclusively confined to that series; 44, or nearly 20 per cent, are common to it and the James River series and have no further distribution; 73, or over 33 per cent, are common to the Rappahannock and James River series, 25 of which, or over 12 per cent, are found at higher horizons.

THE MOUNT VERNON FLORA.

Only 42 distinct forms from this horizon have as yet been given names, which is less than 6 per cent of the entire Potomac flora; but the collections already made contain a considerable number of new species, some of them very well preserved, whose affinities have not yet been satisfactorily made out. These collections have been the result of three different visits to the localities at Mount Vernon and White House Bluff, in all of which both the time for collecting and the facilities for transporting the fossils were greatly limited and we were obliged to abandon the work at the point where it seemed to have become the most interesting. Notwithstanding the uncertainty that attends all collecting in the clays of the Potomac formation, I can not help feeling that the possibilities are still very great, if not practically unlimited, at these localities.

In considering the relations of this flora to the others it will be profitable to deal with some of the species separately. Lying as the beds do directly intermediate between the Rappahannock and Aquia Creek series, it is important to note what plants are found below and what

[1] Mon. U. S. Geol. Survey, Vol. XV, 1889, pp. 17–18.

[2] Bull. U. S. Geol. Survey No. 56, 1889, p. 46, pl. ii, fig. 5; pl. iii, figs. 1–5.

ones above, as well as those that occur both below and above. To the first class, viz, those found only at a lower horizon, belong *Zamites tenuinervis* Font., which is found in both the James River and the Rappahannock series, and also occurs in the flora of the Trinity division, in Texas, and *Z. crassinervis* Font., otherwise confined to the Rappahannock; also *Cladophlebis rotundata* Font., confined to the Rappahannock, and *Thyrsopteris brevifolia* Font., confined to the James River series. There is also the dicotyledonous leaf, *Ficophyllum tenuinerve* Font., hitherto confined to the Rappahannock series. Of the second class, viz, not found below but occurring in the Aquia Creek series, we have *Baieropsis denticulata angustifolia* Font., and two dicotyledonous leaves, viz, *Menispermites virginiensis* Font., and *Proteæphyllum reniforme* Font. Of those that pass up from the Older Potomac into the Aquia Creek series there is the widely distributed *Thyrsopteris rarinervis* Font., which also occurs in both the Trinity and Shasta group, *T. decurrens* Font., and *T. bella* Font., *Sphenopteris latiloba* Font., and *Cladophlebis constricta* Font., which are also Kootanie species, *Nageiopsis longifolia* Font., common also to the Shasta group, and *Sphenolepidium Sternbergianum* (Dunk.) Heer; while of dicotyledons we have *Myrica brookensis* Font., and *Rogersia angustifolia* Font. There are a few forms which are believed to be identical with Amboy Clay species. One of these is *Sphenopteris grevillioides* Heer, found only by Mr. White at Gay Head, but so near to the form referred by Newberry to *Asplenium Foersteri* Deb. and Ett., that it may be necessary to unite them. There is also a cycadean leaf which seems to be *Podozamites marginatus* Heer. One of the forms of Celastrophyllum is very closely related to, if not identical with, *C. Brittonianum* Hollick, from the Amboy Clays.

These enumerations are sufficient to show the intermediate character of this flora. But what gives it its chief interest is the occurrence of a number of entirely distinct forms not hitherto found in any part of the Potomac formation. Some of these I have thought it worth while to illustrate in this paper.

On Pl. II, Figs. 1, 1*a*, 2, 3, is shown a delicate little fern which undoubtedly belongs to the genus Scleropteris. I am satisfied from intermediate forms that all these figures belong to the same species. Fig. 1*a* represents the small fragment, Fig. 1, magnified three diameters. A comparison of these forms with *Scleropteris tennisecta* Sap.,[1] from the Upper Jurassic (Kimmeridgian) of France, shows a very close resemblance, but the European form is often much more branched and larger. But for the considerable difference of age and the wide geographic separation the American form might perhaps be regarded as only a variety, but under the circumstances it seems better to treat it as a distinct species. I have therefore decided to name it *S. vernonensis.*

The specimens figured on Pl. II, Fig. 6, were on one large slab, as

[1] Plantes Jurassiques, Vol. IV, pl. liv, figs. 2–4; pl. lv, figs. 6, 7; pl. lx, fig. 5; pl. lxi.

they appear in the figure. The leaf is clearly cycadaceous, and resembles many of the specimens that have been referred to *Zamites tenuinervis* Font., where the base is not shown. In the present case the absolute base is not preserved, but the narrowing which takes place immediately above the base would seem to indicate that it reached the rachis in a point. It does not therefore agree with the characters of Zamites, but neither does it agree with those of Podozamites. The fruit which occupies the lower right-hand corner bears a very strong resemblance to that of some species of Zamia. It is about the same size and form as the immature fruits of *Zamia integrifolia* Willd., collected by Mrs. Ward and myself at Dunnellon, Fla., in April, 1891, which I caused to be figured for the Century Dictionary under the word *Zamia*. The specimen is preserved in alcohol, and I have carefully compared it with the fossil. Some of the leaves of Zamia proceed from a point, and there is nothing in the present leaf that is opposed to its reference to that genus. The presumption is strong that the leaf belongs to the same plant as the cone. I know of nothing in the fossil state with which it can be identified, and the leaf does not agree with that of the living species with which I have compared the cone. I am therefore obliged to regard it as a new species, and will name it *Zamia Washingtoniana*, thus dedicating it to Washington, whose tomb is so near the spot where the plant flourished.[1]

The specimen figured on Pl. III, Fig. 2, is of unusual interest. It occurs on the same slab with the plant last described, and also with the one represented in Fig. 4 of Pl. III. The impression on the slab is clear, and reminds one at first sight of certain herbaceous forms with sheathing joints, as, for example, Lychnis and the rush-like Fuirena and Dulichium. The specimen shows three of these joints, in the lowermost of which the sheath has fallen away. In the middle joint the sheath is clearly preserved, causing an enlargement of the node, apparently consisting of a single piece, and having a crown of distinct teeth at the summit. Four of these are visible upon the face that is presented in the impression. From beneath this sheath, at its summit, there are clear indications of two protruding objects, differing somewhat in form, but both of which may have been the bases of branches which had borne flowers. The third node has the sheath still better preserved, which enlarges upward and is crowned by a row of teeth, of which six are visible in the impression. From beneath this sheath three flattened scales similar to one of those at the next sheath below are distinctly seen. These give at first the impression of an inner sheath emerging from beneath the outer one, but it seems more probable that they are also the bases of branches. This view is strengthened by the occurrence of what looks like an inflorescence on the opposite side of the

[1] The distance is less than a mile. It is also worth noting that Washington's tomb stands on the slope at about the top of the Rappahannock freestone. Very likely it may have been purposely so located in order to secure a basis on solid rock. If this is the case the excavation must have been made in the Mount Vernon Clays, which always occupy that position.

stem at about the same level as the summit of these scales, as if borne upon one of these branches that emerged from the side of the stem opposite the beholder. A little above this, on the left, is seen an elongated body which may have proceeded from the same sheath. Still higher up on the left and from what would appear to be the center of an internode, but which is probably a true node from which the sheath has entirely disappeared, there proceeds a short, scaly stem bearing a large and distinct ament or immature fruit, the basal portion of which is covered with scales and the terminal part of which seems to consist, so far as can be seen, of larger enveloping scales inclosing the flowers. These are much longer than the lower ones, and terminate in an acute point which is sometimes bent inward at the tip, the body of the scale being partially reflexed. Assuming this to proceed from a node, the next internode above is shorter than the one below, but the expansion of the stem at the node is clearly perceptible, and several of the scales of the sheath are preserved. From this node there appear to have proceeded several flowering branches, remains of three of which are shown in the specimen. The one on the right has disappeared, except the base of the stem showing the mode of insertion. On the left, however, we have another well-preserved ament similar to the one below, but somewhat smaller and apparently less mature. From what can be seen of the scales on the lower portion, they appear to have been slightly reflexed or squarrose. The terminal ones have the same character as those of the next lower ament, but are better preserved, and the tips of nearly all of them are distinctly bent backward. Immediately above this ament there are the remains of another one, of which only the terminal scales are preserved. Some other imperfect bodies can be seen at the same level on the right of the stem, which may be the remains of still another ament.

The whole plant shows distinct longitudinal ribs with intermediate grooves, and the elevated portions are seen to pass into the scales of the sheaths, which are probably consolidated into a single piece, at least below.

In endeavoring to determine the type of vegetation to which these several characters most clearly point, great difficulties have been encountered. I have shown both the specimen and the drawing to a number of well-known botanists, and especially to Mr. Frederick V. Coville, botanist of the Department of Agriculture, who accompanied me on several of my expeditions to the Mount Vernon beds. It was he who first suggested the possible relation of this plant to Casuarina, and we have together compared it with all the living forms in the National Herbarium.

I have also carefully examined all the fossil species that have been figured, including *C. Sotzkiana* (Ung.) Ett., which Unger referred to Ephedrites, as related to Ephedra. Ettingshausen reexamined the material and found small branches bearing the characteristic nodes and

scales of Casuarina, and it has since been generally referred to that genus. I find no cases in which stems as large as those of the plant under discussion bear such scales, but in some species, as *C. glauca* Sieber and *C. torulosa* Ait., such branches are much larger than those of *C. equisetifolia* Forst. Moreover, the male inflorescence of Casuarina is terminal, or forms a terminal spike or ament; but in some species, as *C. quadrivalvis* Labill., this terminal spike becomes elongated, revealing its true nature as consisting of a series of nodes with imbricated sheaths, from underneath which the male flowers, reduced to mere stamens, project. I have represented this in Fig. 4 of Pl. III, from a specimen in the National Herbarium from Tasmania. Fig. 4*a*, enlarged two diameters, brings it to about the dimensions of the fossil plant.

Except, however, that in Ephedra the scales are wanting, the resemblance is much greater to some species of that genus, and the male plants of *Ephedra monostachya* L. (*E. vulgaris* Rich.) or *E. fragilis* Desf., as figured by Göppert in his Bernstein Flora (pl. iv, fig. 11) and by Unger in his Flora of Sotzka (pl. v, fig. *a*), bear a striking resemblance to it.

I have not overlooked a certain superficial resemblance which this fossil bears in the character of the joints and sheaths, as well as in the striation of the stem, to the living genus Frenela, and especially to Schenk's fossil genus Frenelopsis. Our American species of Frenelopsis, as described by Fontaine, lack these characters almost entirely, at least so far as the specimens show, but some of the figures of the smaller branches of *F. Hoheneggeri* (Ett.) Schenk, figured by Schenk, approach it more closely, though the organs that proceed from beneath the scales are always lesser branches and not flower bearing, and the inflorescence in general is wholly different. Saporta's extinct genus Philibertia, formerly supposed to belong to Frenelites, and some of the branches of which he had referred to Equisetum, seems to have a still closer resemblance to the Mount Vernon plant. Saporta unites with it the *Casuarina Haidingeri* of Ettingshausen, at least in part, and the latter's figures (Tert. Fl. Häring, pl. ix, figs. 17, 18), though much smaller, show when enlarged (fig. *β*) a marked approach to our plant, while some of Saporta's figures of Philibertia (Ann. Sci. Nat., 7e sér., Bot., Vol. VII, 1888, pl. iii, figs. 6*a*, 6*b*, 7, 7*a*) have the stems, joints, and sheathing scales more nearly like those of the Potomac form than any others that I have been able to find. Still, from consideration of the reproductive parts and the general description given by Saporta it is impossible to believe that it belongs to that genus.

Returning to our comparisons with Casuarina, it is evident that the fossil plant, notwithstanding the close resemblance in the stem and sheaths, can not be the exact homologue of the male plant of that genus. As already remarked, the staminate aments are always terminal. In our plant the flowers are obviously borne on short stems which proceed from the nodes. The inflorescence described is therefore

clearly in the nature of an ament. Each of these would thus represent, homologically, the entire male ament of most species of Casuarina, even the elongated one of *C. quadrivalvis*, of which Figs. 4 and 4*a* show only a few of the lower nodes. Above these the nodes become contracted, the internodes disappearing entirely and the inflorescence taking the form of an elongated spike or catkin. If, however, we turn now to the female inflorescence we find a somewhat different state of things. Here in most species no distinct sheath is found on the principal stems, but these are jointed and ribbed, and the ribs are terminated at the nodes by a crown of scales imitating sheaths. From the axis of these principal nodes, or apparently from beneath the sheaths, there proceed short flower-bearing branches, provided with close scales, ovate in shape. At the summits of these short branches the fertile aments are borne in the form of more or less spherical heads or cones. These are also covered with scales similar to those on the stem, the upper ones being more elongated, sharp pointed, and reflexed. In their maturer stages these latter scales very closely resemble those of the fossil. Fig. 3 shows four of these nodes, two of them giving off flower-bearing branches, drawn from a specimen of Casuarina found in the National Herbarium, upon the label to which it is said to have been cultivated in Italy, to have belonged to the herbarium of J. T. Moggridge, and to have been received from Kew in 1880; but no specific name is given to the specimen. If this figure be compared in detail with that of the fossil plant it will be admitted that there are many striking resemblances, the chief difference being the absence of a manifest sheath at the nodes of the living plant. Now, it may be supposed that the general type of structure of all the parts of Casuarina was originally the same, and that primarily each node should be provided with a sheath, as is the case in the small ultimate branches of the male plants as seen in Figs. 4 and 4*a*. If we can imagine a species in which such sheaths are present on the larger branches of the female plants no essential difference would exist between such a species and the fossil species under consideration, and it is altogether probable from the nature of the inflorescence of the fossil plant that it belongs to a fertile branch, and that the aments are female, corresponding to those of Fig. 3.

I have therefore decided upon the whole to refer this form to Casuarina, with all necessary reservation, and to name it, in honor of Mr. Coville, *C. Covillei*. It would certainly be an interesting fact if it were proved that this anomalous type of vegetation lived in America during Lower Cretaceous time. It is in the Potomac formation that the absolutely oldest dicotyledons known have been found. The genus Casuarina has recently been subjected by Treub[1] to a searching investigation, and he decides that it can not properly be placed among the dicotyledons, as has heretofore been done; also that it can not be

[1]Sur les Casuarinées et leur place dans le système naturel; Ann. du Jardin botan. de Buitenzorg, Vol. X, 2me partie, 1891.

regarded as monocotyledonous, while at the same time it is clearly angiospermous. He therefore gives to this sole genus a rank coordinate with that of the combined monocotyledons and dicotyledons, the Chalazogams, all other angiosperms constituting the Porogams. If Treub's conclusions are sustained the genus Casuarina must be regarded as the least-developed angiosperm, and therefore the plant which is most nearly related to the Gymnosperms. As the Gnetaceæ, to which Ephedra belongs, rank highest among the Gymnosperms, the effect of this is to bring the two genera, Ephedra and Casuarina, as near together systematically as they have always seemed to be from their superficial aspect.

Fig. 5 of Pl. III represents a form which must be referred to the genus Sagittaria. All of the leaf except the upper portion is well preserved, although on both sides of the specimen, from a short distance above the base, the margins are rolled under and hidden from view. This is clearly seen in the specimen, and the nerves on the right may be traced some distance around this margin. Unfortunately, the finer nervation is not visible. I have had figured and placed in immediate juxtaposition (Fig. 6) a small leaf of *Sagittaria latifolia* Willd., now growing in the vicinity of Washington. The long, pointed auricles of the latter are represented in the fossil form by short, rounded ones, but all of the principal nerves are the same in both, and may be traced the greater part of their length in the fossil specimen. The two chief lateral nerves probably followed the margin above the middle, as in the living species, but the inflection of the margin makes them appear to terminate below the summit.

I have named this species *S. Victor-Masoni* for Mr. Victor Mason, who has accompanied me in nearly all my expeditions to this part of the Potomac formation, and has actively assisted in making the collections. This leaf was found at the locality in the White House Bluff described above.

The singular object depicted on Pl. III, Fig. 7, though a very definite impression, has nevertheless caused much research, and it still remains very doubtful what manner of plant it represents. Besides the specimen figured, several other less perfect ones occur in the collection, all presenting substantially the same general aspect. The first impression one gains from a casual view of the specimens is that of a large flower, such for example as that of an Iris, or flower-de-luce, and for a long time I had treated it under that name, but when it came to a matter of delineation and very careful study; and especially of comparison with flowers of the living *Iris versicolor* L., most of the resemblances vanished, and it even became doubtful whether it represents a flower at all and not rather the open valves of some dehiscent pod, such as those of the lily family. While only five such valves can be seen, there is room to suppose that a sixth lies concealed behind the other parts. But if there were originally only five it will have to be referred to some

of the dicotyledonous orders. If it represents a flower the same would be true, but it would be necessary to suppose that the petals were of a leathery consistency and were either corrugated laterally along both sides of the median line or else that this corrugation results from the unequal contraction of the relatively thin outer and the very thick keeled central parts. But it is almost possible to distinguish two rows of small granular bodies, arranged along the median line and at right angles to it, which might represent the seeds of a capsule, although the arrangement is quite unusual. It can not be ascertained with certainty whether the several parts are really distinct and somewhat imbricated or whether they may not be united at different distances from the base. The longitudinal striæ, proceeding from the base of each part, are very distinct in the two upper members, but lose themselves before reaching the middle. The peduncle can be seen, as shown in the figure, but it is doubtful whether we here have a view of the lower (outer) or of the upper (inner) portion. Whatever may be true of the three lower lobes, it seems quite certain that we are viewing the inside of the two upper ones. A more exhaustive comparison with a large number of flowers of living plants, and with various capsules and pods, may yet reveal the true affinities of this interesting plant. But time is lacking at present for such researches, and I am compelled to follow the example of most paleobotanists who have discovered floral organs, and to refer it to some one of the comprehensive genera which have been created for the reception of such forms. Even here I seem obliged to decide the question as to whether it is a flower or a fruit, which, as has been seen, can not be done. Upon the whole I can not perhaps do better than to place it in the genus Antholithus. In the specific name, *Gaudium-Rosæ*, I design to commemorate the fact already mentioned that the summit of the bluff immediately over this plant bed was the spot known as Rose's Delight, referring to a member of the Fairfax family who specially delighted in this prospect.

In making collections from the Mount Vernon Clays the forms that first and most forcibly strike the eye are the little leaves of Populus, which are so common in them. The exceedingly definite and perfect character of these impressions leads one at first sight to think of a quite recent formation. The form and outline are strikingly distinct, and the nervation is as clear as the nature of the matrix will allow. But upon comparison with the leaves of living species of Populus, and, indeed, with those from any of the more recent formations, it becomes obvious at once that we here have to do with an altogether distinct type of the genus. In fact, there may be grave doubts as to whether these forms really belong to Populus, and I have taken some trouble to examine a number of other genera, such as Grewia, Paliurus, etc., to see whether they do not more nearly conform to those types. Saporta and Marion have expressed doubts with regard to a number of the

Arctic forms of Populus figured by Heer.[1] But in these they would rather see a resemblance to Cocculus. No such resemblance can be seen in the forms before us, and until further light can be shed upon the problem I shall be obliged to keep them within the genus Populus, to which prima facie they so obviously belong.

The specimens figured on Pl. IV, Figs. 1–4, represent at least two distinct species. I had been disposed to regard the form represented by Fig. 3 as distinct from that represented by Figs. 1 and 2. The serration of the margin is much shallower and the difference seems more marked in the specimens than in the figure. The basal sinus differs slightly, and there is a still greater difference near the apex, which is slightly constricted in Figs. 1 and 2 and not at all in Fig. 3. The nervation of all may be said to be identical, except that it is more slender in Fig. 3, and the midrib especially is much thinner. As the petiole is entirely wanting no comparison of this can be made. The two specimens, Figs. 1 and 2, undoubtedly represent the same form, and the smaller one appears to be somewhat less mature. As this is the first true Populus that has been found in the Older Potomac I have named it *P. potomacensis.*

The other form, Fig. 4, though similar in all other respects to the ones last described, is not only much larger and longer in proportion to its width, but it has a deep acute basal sinus, causing the base to present two distinct auricles, from which circumstance it may be called *P. auriculata.* I am aware that the immature leaves of Populus, and those borne on small shoots at the base of trees and on seedlings, are often much more elongate than the normal type of leaf of the same species, and if this form were diminutive, or bore any evidence of being immature, it might be grouped with the others; but as it is a larger form, and has every appearance of being fully developed, it is neessary to consider it as specifically distinct.

The genus Populus has played a most interesting rôle in the geological history of plants. It is one of the most widespread genera of fossil plants, and the forms which its leaves present are exceedingly variable. It would seem that there must have been several distinct lines along which it has developed. All the species of Populus now living have what may be called a pinnate nervation, that is, it consists mainly of a prominent midrib, from which proceed a greater or less number of secondary nerves. Sometimes there is a pair near the base which are considerably stronger than the rest, but they rarely or never obtain such prominence as to be regarded as primary nerves. Moreover, their general direction is nearly straight, whatever the angle may be, and they do not tend to curve inward toward the midrib in ascending. The late Tertiary types from European beds, for example from Œningen and from the Upper Rhone, conform in the main to this nervation.

[1] Recherches sur les Végétaux Fossiles de Meximieux; Archives du Muséum d'Histoire Naturelle de Lyon, Vol. I, 1876, pp. 264–265.

The Arctic Tertiary types, on the contrary, present a distinct style of nervation. They come within the class which is called palmately nerved leaves—that is, the two nerves that proceed from the summit of the petiole have that degree of prominence which entitles them to be called primary nerves. A special peculiarity of most of these leaves of Populus is that these lateral primaries, instead of proceeding at a given angle more or less directly to the margin, almost immediately begin to curve upward, and ultimately curve inward, the upper extremity sometimes nearly returning to the midrib at the apex, a type of nervation which, when complete, is called acrodrome. Now it is found that the American fossil species of Populus, with a few exceptions, have this latter type of nervation, especially those belonging to the Fort Union group, from which such large numbers have been collected.

The plants that are here under consideration seem to be almost an exaggeration of the type described, which may be called the American type of nervation. But the great peculiarity of our Mount Vernon forms of Populus is their remarkably distinct cordate base. We may suppose that this line of the genus had its origin in America near the base of the Cretaceous, and that it has for its immediate descendants all the more recent American forms that have been found. Our Fort Union group seems to be substantially the same as what has been called the Upper Laramie in western Canada, which the Canadian geologists have succeeded in connecting with the Mackenzie River beds, that have yielded a similar flora, and these in turn would appear to be practically the same as nearly or quite all of the Arctic Tertiary beds, whose flora does not widely differ from it. The genus Populus is found throughout these Arctic beds, and the two species, *P. arctica* Heer and *P. Zaddachi* Heer, found on the north side of Grinnell Land, in latitude 81° 46′ N., give to this genus the distinction of having attained the "farthest north."

For a long time Heer's *Populus primæva* from the Kome beds, was quoted as the most ancient dicotyledonous plant. We have in the Potomac formation, even in the James River series, a considerable number of dicotyledons, some of which are probably related to Populus; but these beds are much older than the Kome beds. If there were any way of correlating the Mount Vernon beds with the Kome beds it would probably be found that they are of nearly the same age. But the forms of Populus from the Mount Vernon Clays are widely different from that of *P. primæva*, which does not possess the American type of nervation.

Taking all these facts into consideration, it will probably be admitted that the genus Populus, historically considered, is the most interesting of all dicotyledonous genera.

The only other one of the numerous forms which can not be identified with anything heretofore described, which I have selected to represent the general character of the Mount Vernon flora, is a delicate,

elongated dicotyledonous leaf (Pl. IV, Fig. 9), nearly lanceolate in form and regularly and finely toothed around its entire border, and which is clearly referable to the comprehensive genus Celastrophyllum, so characteristic of the Potomac formation. But this species differs from all others in several important respects. In the first place, the angle which the secondary nerves make with the midrib is very much less than that of any other species, and gives the plants a considerable resemblance to the pinnules of certain ferns, as, for example, Zamiopsis (compare *Z. longipennis* Font., Flora of the Potomac Formation, pl. lxi, fig. 8). This resemblance is still further heightened by the forking of these nerves, but a close comparison of such dichotomy shows that above the forks the two branches converge somewhat and proceed in a rather irregular manner to the margin. These and other characters, as well as the general aspect, show that our plant can not be a fern, but must be a dicotyledon, and certainly comes within the limits of the genus Celastrophyllum. Two specimens have been collected from the White House Bluff, and in both cases the counterparts are preserved, but in neither have we the entire base of the leaf, so that there is some doubt as to its form. It approaches *C. Brittonianum* Hollick of the Amboy Clays, but there is another form from the Mount Vernon Clays which, from the specimens thus far collected, I am obliged to refer to *C. Brittonianum*, and in this the nervation is quite different. The present form is clearly a new species, and I have named it *C. Hunteri*, for Mr. William Hunter, who accompanied the expedition on which these plants were collected, and to whom, from his lifelong residence in this district, I am indebted for many historical facts in connection with the localities.

In addition to the above-named new species there are a few others of such special importance that I have included them with the illustrations herewith furnished.

On Pl. II, Fig. 4, is represented the pinna of a small fern from the Mount Vernon bed, in which the fruit dots are distinctly shown. In the enlarged figure (4*a*), magnified five diameters, these are seen to be very nearly circular in shape, but in a few cases they are slightly reniform. The plant therefore undoubtedly belongs to the genus Aspidium, but does not exactly agree with any of the published figures. It probably comes nearest to *A. virginicum* Font., and Professor Fontaine, who has seen both the specimen and the figure, is disposed to refer it to that species, which is pinnatifid and of which our plant represents one of the intermediate pinnæ.

On Pl. II, Fig. 5, is shown the best developed of a series of specimens of another fern, which I was at first disposed to refer to *Asplenium Foersteri* Deb. and Ett., from the Aachen beds, Upper Cretaceous (Denkschr. Wien. Akad., Vol. XVII, 1859, pl. ii, figs. 4–7). The resemblance is quite close to fig. 4 of those authors, which seems to represent a defective specimen, but it differs materially from the much better specimen represented in fig. 7. Nevertheless, Dr. Hollick, who is

familiar with the forms found by Dr. Newberry in the Amboy Clays and referred to that species, was of the opinion that the Mount Vernon plants were the same as those of the Raritan, and this may, in fact, be the case. I am, however, more inclined to think that our plant is a form of *Sphenopteris grevillioides* of Heer (Fl. Foss. Arct., Vol. III, pt. 2, pl. xi, figs. 10, 11), and in this Professor Fontaine agrees with me. Mr. David White identified one of the Gay Head specimens with this species (Am. Jour. Sci., 3d ser., Vol. XXXIX, pl. ii, fig. 1). This seems to be somewhat different from Dr. Newberry's specimens, and also from those of the Mount Vernon Clays, but that all of these forms constitute a general group extending from the Older Potomac into the highest beds of the Newer Potomac there seems to be no doubt.

The fine fruiting, coniferous plant represented in Fig. 1 of Pl. III is of very special interest. When first found I supposed it to be a Sequoia, and indeed it has some slight resemblance to forms of *S. fastigiata* Heer from the Cretaceous of Greenland; still, it is clearly not that plant, and the foliage does not agree with that of any species of Sequoia. In the same bed I found undoubted specimens of *Glyptostrobus brookensis* Font., with male aments attached, but neither the scaly branches nor the cones of the specimen under consideration conform to that genus. It is only in the genus Sphenolepidium that we find identical foliage, and that of *S. Sternbergianum* (Dunk.) Heer, as shown by numerous specimens from the Basal Potomac, agrees in this respect so exactly that but for the fruit there would have been no hesitation in referring this plant to that species. Unfortunately no fruiting specimens of *S. Sternbergianum* have been found in America, and those figured by Schenk from the Wealden of Europe possessed somewhat elongated cones, thus differing from those of our plant. In the midst of these difficulties I sent the drawing to Professor Fontaine, whose remarks upon it are as follows:

> This, I think, is certainly *Sphenolepidium Sternbergianum.* The cones have the scale closed, and in this condition do not look like the same when the cones are dissected by the opening of the scales and their partial removal. This latter is the case with the cones of my *S. virginicum,* and in Schenk's figs. 10–13, pl. xvii (Fl. d. Nordwestdeutsch. Wealdenformation) of *S. Sternbergianum.* Your cones are, as you suggest, probably immature, and I think somewhat distorted by pressure. Their immaturity will account for their small size, and the closure of the scales for the difference in appearance from Schenk's cones.

I accept Professor Fontaine's conclusion, and with this discovery of the fruit of this species we have a very complete representation of one of the most common trees of Older Potomac time. In his Flora of the Potomac Formation, Professor Fontaine had figured a large number of "male aments" (pl. xxi) which he could not at the time refer to their appropriate genera. At the locality which I have designated as Chinkapin Hollow I have collected many very similar aments in immediate connection with, and in a few cases actually attached to, the scaly stems of *S. Sternbergianum.* We therefore now have, in addition to the foliage,

the reproductive organs of both sexes of this plant. Moreover, as most of Professor Fontaine's specimens showing the foliage are from the Basal Potomac, and my Chinkapin Hollow locality also belongs to the Rappahannock series, while the aments described by him were found in the Aquia Creek series, the specimen now under consideration from the intermediate Mount Vernon beds establishes the complete geological continuity of this type throughout the whole of the Older Potomac.

The plant figured on Pl. IV, Figs. 5 and 6, is probably, as Professor Fontaine believes, his *Proteæphyllum reniforme*, but the nervation is very much better preserved and brings out the fine areolate character of the meshes in a clear light. A comparison of these specimens with one of Heer's figures of *Chondrophyllum orbiculatum* Heer (Fl. Foss. Arct., Vol. III, pt. 2, pl. xxxi, fig. 3*c*) makes it almost impossible to doubt that he had in hand either this same plant or a very near representative of it. This figure is not sufficiently like the other ones that he gives of *C. orbiculatum* to make it certain that they are the same. It is, however, an interesting fact that several species of Chondrophyllum have been detected in the Amboy Clays and in the Newer Potomac of Alabama and elsewhere. It is possible that when we come to confront all the data under this head we may be able to establish another of those bonds of union which bind together all the members of this great geologic group.

Finally, Figs. 7 and 8 of this same plate represent, according to Professor Fontaine, his *Menispermites virginiensis*, hitherto confined, as were all the Potomac species of the genus, to higher beds, this and *M. tenuinervis* Font. being Aquia Creek species. Dr. Hollick has, however, described two new species from the Amboy Clays, besides identifying the *M. borealis* of Heer. It is proper to say that Dr. Hollick, who saw these specimens, was disposed to refer them to Nelumbo; and I have considerable fragmentary material from the Mount Vernon Clay which indicates, with all necessary certainty, the presence of one or more species of that genus. It is just possible that this form may at least be allied to Nelumbo and represent an aquatic herb.

PLATE II.

PLATE II.

MOUNT VERNON FLORA: FERNS, CYCADACEÆ.

PLATE III.

PLATE III.

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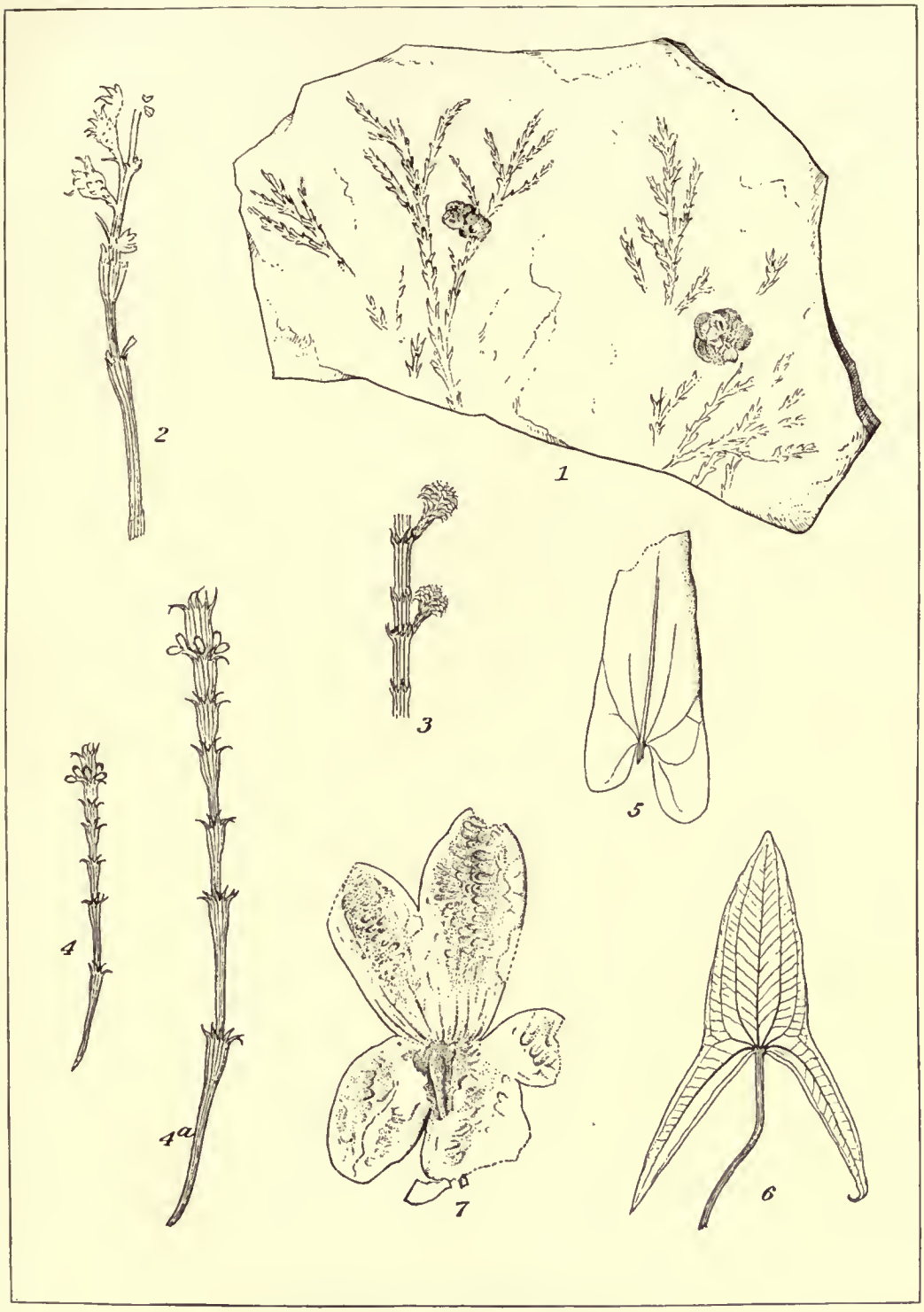
Fig. 6. Sagittaria latifolia Willd. (living) 354
Fig. 7. Antholithus Gaudium-Rosæ n. sp 355



MOUNT VERNON FLORA: CONIFERÆ, CASUARINACEÆ, MONOCOTYLEDONS.

PLATE IV.

PLATE IV.

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MOUNT VERNON FLORA: D.COTYLEDONS.

THE AQUIA CREEK FLORA.

The Aquia Creek series has yielded 137 species, which is nearly 19 per cent of the total known Potomac flora. Of these, 57, or a little over 40 per cent, occur in the lower beds, while only 9, or less than 7 per cent, are found at a higher horizon. Sixty-seven, or nearly 49 per cent, are confined to that series. These facts show that notwithstanding the important interruption indicated by both the stratigraphy and the paleontology between the Basal Potomac and the Aquia Creek series, these beds must be classed with the former, as belonging to the more ancient deposits.

It might appear at first sight, when contemplating the well-marked dicotyledonous plants of the Mount Vernon Clays to which attention has been called, that they represent a flora as highly developed as that of the Aquia Creek series. But, as has been seen, the nervation of the species of Populus is different from that of any other known species of that genus. The Menispermites is an Aquia Creek species, the Proteæphyllum passes up from the Rappahannock into the Aquia Creek series, and the Celastrophyllum is quite anomalous. If we turn to the other types we find that they are either silent on the question or else that, as in the Scleropteris, they point back to the Upper Jurassic.

In our present limited knowledge of the Mount Vernon flora, therefore, we may say of the Aquia Creek series that we have here for the first time a well-marked dicotyledonous flora, in which both the form and nervation of the leaves begin to approximate those of modern times. Perhaps the most interesting genus is Celastropyllum, a type of plants with dentate or crenate leaves and nervation approaching that of the Celastraceæ. These forms can be traced throughout the entire Lower Cretaceous, one species, *C. proteoides* Font., occurring in the James River series, another, *C. arcinerve* Font., in the Rappahannock series, and I have already mentioned the two from the Mount Vernon Clays. But when we reach the Aquia Creek beds we find no less than ten distinct forms of this type, with their character much more highly developed. Four of these recur in the higher beds, though probably with slight modification in the same direction of greater definiteness, and this becomes one of the important types of the flora of the Amboy Clays and of all the beds of practically the same horizon, about eighteen different forms having been enumerated by Dr. Newberry and Dr. Hollick.

Another important genus of chiefly Aquia Creek plants is the Sapindopsis of Fontaine. This type was believed by him to have originated in the Rappahannock series, and two species, *S. cordata* Font. and *S. elliptica* Font., are described from Fredericksburg. The Aquia Creek series contains six species, all distinct from these, but presenting a somewhat varied and highly differentiated aspect. The leaves are not strictly pinnate, like those of Sapindus; although the lower leaflets are usually distinct, the upper ones are more commonly grown together so as

to be rather lobed than pinnate. It is difficult to find the analogue of this feature in modern plants, except among the ferns and other low types; but I have seen leaves of *Rhus copallina* L. with the terminal leaflets confluent in this manner. This genus does not appear in the lists as recurring in the Amboy Clays, but Dr. Newberry's Fontainea is almost certainly its direct descendant, and should perhaps be classed in the same genus. These are the most common forms in the Aquia Creek series, and being so closely confined to it and so abundant, they constitute an excellent test of age wherever found.

The leading distinction, then, between this Middle Potomac flora and that of the Basal Potomac is in the predominance of dicotyledons; but the proof of its more direct connection with the lower beds consists in the persistence of simpler types—ferns, to some extent, but especially conifers. That peculiar intermediate genus, Nageiopsis, which seems almost to bridge over the interval between the cycad and the conifer, and of which fourteen species have been described, all occurring in the lower beds, illustrates this by the persistence of four of these species in the Aquia Creek series, and two of these, *N. angustifolia* Font. and *N. longifolia* Font., are found in the Mount Vernon Clays also. The last named has recently been detected in the Shasta group of California.

INTERMEDIATE FLORAS.

Up to the present date no fossil plants are known from the Iron Ore Clays proper. They consist of massive red clays, without lines of stratification, sand veins, or other evidences of interrupted sedimentation. In many places, especially in the iron ore regions, they abound in ferruginous crusts, and sometimes present regular shale, which, however, is obviously not the result of sedimentation, but represents lines along which the iron infiltration has been arrested and lithification has taken place. Concretions of all forms and regular geodes, together with all the multiform objects which characterize bog ore, are to be found; and sometimes there is to be seen upon such objects clear evidence of plant impressions, but always, so far as observed, of such a character as not to reveal the structure of the plant. When I first began my investigations, after having carefully studied the Fredericksburg freestone as seen at Alum Rock and other points, containing so many impressions of stems and even large trunks, but without showing the more delicate organs, and then subsequently examining the Iron Ore Clays and finding similar impressions in them, I framed the theory that the Iron Ore Clays of Maryland might be the more northern homologue of the Virginia freestone; although the former is always white and destitute of iron, while the latter is always red or brown and charged with the iron oxide. But a more thorough acquaintance with the general region of the Iron Ore Clays soon showed me the impossibility of this, and revealed the fact that the true Rappahannock series, resembling in most respects, except that of actual lithification, the more southern

exposures, is always to be found underneath the red clays. This has already been sufficiently dwelt upon, and it need only be added that the greater part of these impressions of plants are observed to occur near the line of contact between the clays and the underlying sands (paint stone, etc.), so that it is usually a question to which of these series such impressions actually belong. Of course, under such circumstances I am disposed to assume that they probably belong to the lower of the two beds, in which case they would really be the homologue of those found in the Rappahannock freestone. It therefore becomes all the more probable that the Iron Ore Clays proper may contain no fossil plants.

THE LOWER ALBIRUPEAN FLORA.

The question, then, arises whether there are any beds from which fossil plants have been obtained which can be regarded as truly intermediate between the Aquia Creek series and the Amboy Clays and their equivalents. As I have already intimated, the several plant-bearing horizons belonging to the Albirupean series in the State of Maryland and the District of Columbia very probably represent those of the Raritan formation of New Jersey, which may be regarded as an immense thickening of them. The fact that in the limited collections from the Maryland beds so many of the forms are identical with or similar to those of the Amboy Clays seems to prove this, and while these more southern deposits may differ considerably in their geological position, the same is certainly true of the New Jersey deposits, those of Woodbridge, Sayreville, and Milltown being undoubtedly considerably lower than those of South Amboy, while a marked difference is often to be noticed in the horizon at which plants are found in the same clay pit, as some of these pits have a depth of 100 feet or more.

There are only two localities which I have suspected of occupying some such intermediate position. One of these is the plant bed on Pennsylvania avenue extended, in the District of Columbia, near the Anacostia River. There are here really two localities at the same horizon, not more than half a mile apart. The one which has yielded most of the plants is just below the crest of the hill, in a deep cutting made for the roadway. The plants came from the vein not over 10 feet above the top of the red clays, which undoubtedly belong to the Iron Ore series. But it is also not over 10 or 15 feet below the Miocene (Chesapeake) which caps the hill. Indeed, the Chesapeake formation at this point contains at its base a great many clay pellets redeposited from the Potomac, and in some of these, 20 feet above the plant layer, impressions of leaves evidently of Potomac plants were once found by Dr. Rothpletz and myself.

At one restricted horizon in this thin Upper Potomac bed a large collection of plants was made. They are very fragmentary, the clays breaking easily across, so as to render it impossible to obtain large

pieces. As the leaves are nearly all large, this breaks them up to such an extent that perfect ones can scarcely be secured. Nevertheless, 12 different forms have been provisionally determined from this collection, which show a very mixed grouping. Most of them are comparable to Amboy Clay species, and two have been compared with Dakota forms—at least we seem certainly to have the genus Protophyllum, which is characteristic of the Dakota formation. Nevertheless, Professor Fontaine, who has examined the collection, has identified with certainty at least one Aquia Creek species, *Populophyllum crassinerve* Font. *Sequoia subulata* Heer occurs here, which is not found in the Aquia Creek series, but is found in both the basal members. It also occurs at Sayreville on the Raritan. The widely distributed *Asplenium Dicksonianum* Heer is also present. Most of the other forms can be compared with those of the Amboy Clays. The flora of this bed would therefore seem to be somewhat older than most of the others.

The other supposed intermediate flora is from one of the localities in Alabama, viz, at Snow's plantation, on the Black Warrior River, 9 miles below Tuscaloosa, and only a few feet above the river bed. The plants differ considerably from those found at the other localities in Alabama, and indicate a lower horizon. *Cladophlebis parva* Font., a Rappahannock species, and *Sequoia ambigua* Heer, a Greenland Cretaceous species found in the James River series, according to Fontaine, occur in this bed. There is a species of Celastrophyllum which very closely resembles one that occurs at Fort Foote, associated with *Nageiopsis angustifolia* Font., and other characteristic Aquia Creek species. There is also a species of Laricopsis which can scarcely be distinguished from *L. longifolia* Font. of the James River series. In fact, the genus is confined to the lowest Cretaceous, i. e., to the James River and the Trinity. The significance of its occurrence at Snow's plantation is therefore very difficult to understand.

These beds have yielded 19 species in all, 5 of which, if we include the Laricopsis, are found at lower levels. Three are undetermined forms confined to this bed, and the remainder have either been identified with or compared to Amboy Clay species. Upon the whole, we may consider this flora as representing a horizon somewhat lower than that of any of the other localities in the Albirupean series, unless it be the one last considered.

Thirty-one species, or a little over 4 per cent of the total Potomac flora, have been found at these two localities.

THE UPPER ALBIRUPEAN FLORA (AMBOY CLAYS AND THEIR EQUIVALENT).

The rest of the Albirupean flora is, in the present condition of our knowledge and so far as the comparisons we are now making are concerned, substantially the same as the flora of the Amboy Clays and of the Cretaceous of Staten Island and Long Island, as these have been elaborated by Newberry and Hollick. As already remarked, the most

that it has been sought to accomplish is the identification of the forms from other localities with these last. The localities from which collections have been made for such comparison, taken in their order from southwest to northeast, are as follows:

1. The great railroad cutting near Pocahontas, in Tennessee, which has been many times visited by geologists and the age of which was never settled until the summer of 1891, when Mr. McGee's party visited it, has yielded one species, collected at that time by Prof. Robert T. Hill, which proves to be the *Eucalyptus attenuata* of Newberry. Mr. McGee, upon the stratigraphical evidence presented, pronounced the formation Cretaceous, and Professor Hill's specimen practically fixes it as the equivalent of the Tuscaloosa formation.

2. Locality on the Kansas City, Memphis, and Birmingham Railroad in Alabama, at Glen Allen, this being the name of the railroad station. From this locality a large collection was made by Dr. Eugene A. Smith and myself in 1892, and more than 20 of the species in that collection have been either identified with or found to be closely related to Amboy Clay species.

3. At Shirley's mill, on Davis Creek, 11 miles south of Fayetteville, in Fayette County, Ala., a still larger collection was made during the same expedition. The specimens are in an admirable state of preservation and over 50 species have been provisionally identified, chiefly with Amboy Clay forms.

4. At three localities in or near the city of Tuscaloosa 7 or 8 species have been partially identified.

5. Near Cottondale, 8 miles east of Tuscaloosa, Professor Fontaine made a large collection in 1887. This has yielded about 40 more or less determinable forms, most of which are compared with Amboy Clay species.

6. Near Brightseat, Md., 10 miles east of Washington, 3 of the species of sassafras found in the Amboy Clays have been collected.

7. On the abandoned Drum Point Railroad, near where it crosses Severn Run, 5 different forms were collected by Mr. David White, which can be compared with those of the Amboy Clays, and some of which are probably specifically identical.

8. At Round Bay, on the north side of the Severn River, half a mile above the landing, some dark carbonaceous shales and clays, only a few feet above tide, have yielded about a dozen plants which are clearly of Amboy types. Notable among these is the *Fontainea grandifolia* of Newberry. At least 2 species of Andromeda, *A. Parlatorii* Heer and *A. flexuosa* Newb., also certainly occur, as do *Widdringtonites Reichii* (Ett.) Heer, *Chondrites flexuosa* Newb., *Czekanowskia capillaris* Newb., and *Gleichenia micromera* Heer. A number of other forms were provisionally identified.

9. In the bluff a short distance above the pavilion on Round Bay and immediately underneath the overlying marine Cretaceous is a thin,

light-colored clay layer in which *Eucalyptus nervosa* Newb., *E. attenuata* Newb., and several other Amboy Clay types were collected. This bluff is about 20 feet high, and allowing for the dip the plant bed is probably 30 or 40 feet above the last named.

10. A short distance below Bodkin Point, which lies below the mouth of the Patapsco, clay layers similar to those last described and having nearly the same relation with the marine Cretaceous have yielded *Eucalyptus attenuata* Newb., *Andromeda latifolia* Newb., *A. Parlatorii* Heer, *Myrsine borealis* Heer, and *Sequoia Reichenbachi* (Gein.) Heer, all of which are found in the Amboy Clays.

11. The most important plant bed in Maryland at this horizon is that of Grove Point at the mouth of the Sassafras River, on the eastern shore of the Chesapeake Bay. It has yielded about 40 species, nearly all of which have been identified with Amboy Clay forms embracing the greater part of the characteristic species of the New Jersey beds. The plant bed, which is in rather coarse arenaceous clay situated near the water's edge, rises some 10 to 15 feet and is overlain by the Clay Marls, which are here quite thin, but are developed to a great thickness on the opposite side of the Sassafras River between Betterton and Howell's Point. This locality has the further advantage of having its stratigraphical position clearly shown. Perhaps the most instructive section of the Potomac formation that has been discovered is that which I have called the Chesapeake section; it can be worked out very satisfactorily from the Baltimore and Ohio Railroad between Foys Hill and the Little Elk River, southward to the mouth of Principio Creek and thence along the eastern shore of Northeast River, Elk River, and the bay to the Sassafras. The fine bluffs along these shores show the gradual ascent of the Potomac strata through the entire thickness of the great clay series to where they finally dip beneath the water a short distance above Betterton and pass under the Clay Marls and marine Cretaceous deposits. In this section we have every phase of the Potomac formation, from the lilac clays of the James River series to the top of the Albirupean. It is probable that the Raritan section merely represents a great thickening of the upper clay series and that the Grove Point plant bed corresponds with similar strata which may be seen a short distance east of South Amboy and also in some of the clay pits occupying an elevated position directly south of that place.

I shall not include in this enumeration the several collections that have been made by Mr. David White, Mr. Charles H. Meade, and myself in the Raritan region, although many of our specimens have proved to be the same as those studied by Dr. Newberry. I shall also pass over Dr. Hollick's collections from Staten Island and Long Island, and Mr. White's collections from Long Island, because these have been for the most part published.

12. The extensive collections which were made by Mr. David White on Marthas Vineyard, chiefly at Gay Head, but also in the Weyquosque

cliff on the south shore of the island, at Indian Head, and several other localities, have also been subjected to a careful comparison with the flora of the Amboy Clays, and are found to agree in a large number of the forms obtained. As has been previously stated, these plants occur in a different matrix from that of any that have been collected on the Raritan, viz, in ferruginous nodules embedded in the clays. Dr. Newberry mentions vegetable remains in such nodules at Keyport, which is the most easterly point at which any plants have been found in the Raritan section, and therefore presumably represents a higher horizon.[1] As already remarked (supra, p. 335), all the plant beds of Staten Island, Long Island, and Marthas Vineyard, constituting the Island series, consist of clays containing ferruginous nodules which hold the impressions, and probably represent a somewhat higher horizon and the highest thus far known in the Potomac formation. That there is no very wide distinction between them and the Raritan beds is proved by the recurrence of so large a number of Amboy Clay species. Most of the characteristic types are found here, but with them are others which have a somewhat modern facies. The genus Liriodendropsis, with its peculiar areolate nervation, may be regarded as a dominant type of these higher beds, and probably there will be found to be 5 or 6 species of that form, though the *L. simplex* Newb. and *L. angustifolia* Newb. are the most abundant.

The statement has been made[2] that in Dr. Hollick's recent enumerations of the Cretaceous plants of Long Island[3] he has identified 23 out of the 50 species known with those of the Dakota group. Such an inference might, it is true, be hastily drawn from his table of distribution, but to say that a species has been reported from the Dakota group is a very different thing from saying that it is a Dakota group species. It is certainly not correct to say that 23 out of the 50 species found on Long Island are Dakota group species. A slight inspection of his table shows that 12 of these are Greenland species named by Heer, which Lesquereux supposed that he detected in the Dakota group. Some of his identifications are doubtless correct, but a number of them are doubtful, and to several he has himself affixed query marks. It has already been sufficiently shown that there is a close affinity between the Amboy Clay flora and that of the Cretaceous of Greenland. It is probable that the latter constitutes a simple continuation of the Cretaceous of the Atlantic border, and therefore the flora would naturally be similar. Even if the Atane beds are higher than the highest American

[1] Dr. Newberry's specimens are supposed to have come from the bluff under Cliffwood, across the Matawan from Keyport. On July 26, 1894, I visited this bluff in company with Dr. N. L. Britton and Dr. Arthur Hollick. We found the lower portion of it to consist of marine Cretaceous beds belonging to the Clay Marls or the Matawan formation, in which vegetable remains in a fair state of preservation occur.

[2] Am. Jour. Sci., 3d ser., Vol. XLVII, May, 1894, p. 402.

[3] Some Further Notes on the Geology of the North Shore of Long Island, Trans. N. Y. Acad. Sci., Vol. XIII, 1894 (Contributions from the Geological Department of Columbia College, No. XVIII, sec. ond paper, Jan. 22, 1894), pp. 122–132. See Table of Distribution facing p. 130.

strata, the flora would contain the immediate descendants of the former, and many of the same species would persist. This has been sufficiently shown by Dr. Newberry in his Flora of the Amboy Clays, now in press, and is no argument that the Amboy Clays are not somewhat lower than these beds.

In the second place, it must be admitted that Dr. Hollick has identified a number of these with true Dakota group plants on entirely too imperfect material. For example, his *Salix proteæfolia flexuosa* can scarcely be that of Lesquereux and should have been made a new species. His *Sassafras acutilobum* lacks the lobes by which alone it could be identified, and the base is not precisely that of Lesquereux's plant. His *Leguminosites convolutus*, which he himself questions, is based upon a very small fragment of the lower portion, which might be that of either *L. convolutus* Lx. or *L. constrictus* Lx., and the leaf that he identified with the last named has a wedge-shaped or acute base and can not belong to that species. The leaf which he doubtfully refers to Lesquereux's *Celastrophyllum decurrens*, but which lacks the margins necessary for its identification, seems to me to have the areolate nervation of a Liriodendropsis. Finally, one species, *Liriodendron simplex* Newb., which Dr. Newberry changed to Liriodondropsis on account of the nervation, is not found in the Dakota group at all. With the exception, therefore, of *Proteoides daphnogenoides* Heer, *Diospyros rotundifolia* Lx., and probably *Liriodendron primævum* Newb., all of the 23 species enumerated in Dr. Hollick's list as found in the Dakota group are either Greenland species or are of doubtful identification.

Dr. Hollick's inclination to identify Eastern Cretaceous plants with remote forms described from Europe or western America, at higher horizons, though doubtless due to a laudable desire to avoid the multiplication of species, is based upon a thoroughly false principle and must necessarily lead to great confusion. Upon mere fragments he has announced the occurrence in the Cretaceous of Long Island of *Celastrophyllum Benedeni* Sap. and Mar., from the Gelinden beds of Belgium, lowest Eocene, and *Grewiopsis viburnifolia* Ward, from the Fort Union group of Montana. A comparison of these cases shows that this is not justifiable in either of them. The only sound principle is that such remote and improbable identifications should be made only where the evidence is overwhelming. Doubtful forms, if worth recording at all, should be treated as new. If they are subsequently found to belong to known species it is much easier to combine them than it is to separate them from species to which they do not belong. So that, aside from the danger of furnishing the basis for false generalizations, which is the principal consideration, the interests of literature and taxonomy demand that great care be exercised in such matters.

The number of species thus far determined from all the beds that I have included in the Albirnpean amounts to 347, or 47 per cent of the

total known Potomac flora. This is therefore much the largest of all the floras thus far enumerated. It is larger than the combined James River and Rappahannock floras, which, when the forms common to the two are deducted, aggregates 305 species. If to these we add the Mount Vernon and Aquia Creek species not found below, 99 in number, we have for the Older Potomac 405 species, or 55 per cent. As most of the undetermined material is from the Newer Potomac, it may be roughly stated that the Older and Newer Potomac have at the present time each about the same number of species in the collections. But the striking fact is the small number of Older Potomac forms that ever reach these higher beds. Only 15 such forms have been detected, or a little more than 4 per cent of the latter flora. This certainly indicates, from the paleontological standpoint alone, a radical difference between the lower and the upper beds. The intermediate horizons, which I have considered, only partially remove these difficulties. Were it not that it is impossible to discover any clear stratigraphical interval, any evidence of a great time hiatus, any general erosion plane, even such as occurs between the Rappahannock and Aquia Creek series, we should certainly be justified, from paleontological considerations alone, in dividing this great geological unit into two distinct formations. But in the absence of such stratigraphical distinctions we are obliged to treat it as a whole, and when we remember that the great clay series, beginning with the base of the Iron Ore Clays and extending to the Alternating Clay-Sands of the upper beds, is, so far as known, wholly nonfossiliferous, we are obliged to conclude that it was during the long period required to deposit these beds, a period that may have been much more extended than that which would be required to deposit a greater thickness of sand and gravel, that the radical change took place between the chiefly filicine, cycadean, and coniferous flora of the Older Potomac and the chiefly dicotyledonous flora of the Newer Potomac.

The numerical relations of the several subfloras of the Potomac formation, as above set forth, may be presented in the following tabular form:

	Number of species.	Per cent of total.
Potomac flora	737	.....
A. Older Potomac	405	55
I. Basal Potomac	329	44.6
1. James River	152	20.6
2. Rappahannock	221	30
3. Mount Vernon	42	5.7
II. Middle Potomac	137	18.6
4. Aquia Creek	137	18.6
B. Newer Potomac	347	47.1
5. Lower Albirupean	31	4.2
6. Amboy Clays and equivalents	253	34.2
7. Island series	133	18

CORRELATION OF THE FLORAS.

In the following correlation of the several floras of the Potomac formation I shall confine myself entirely to their internal relations and leave out of the account, for the present, the general subject of foreign distribution.

As already stated, the total flora thus far enumerated embraces 737 distinct forms. Some of these are not yet specifically determined, while a few are treated as varieties. To avoid multiplication of words the term "species" will be used for them all. As always happens, especially in floras as unique as that of the Potomac, the greater part of these are more or less rare and are confined to a single horizon, often to a single locality; in many cases only one specimen has been found. These, of course, are not available for purposes of correlation, and it will be necessary to confine the discussion to those species which are common to at least two of the six series into which the formation has been subdivided. The number of species that come under this head is 140, or 19 per cent of the total flora. The question of relative abundance has already been considered, and we are now restricted to the numerical relations alone. These have been stated in a general way in discussing the several series. It is now proposed to enumerate the plants that come under the leading groups forming the elements of this correlation. The object is to show what plants are common to two or more of the series, and it will be convenient, as before, to deal with the lowest members first, and with the others in their ascending order.

It was seen that 44 species were confined to the Basal Potomac, but occur in both of its members. These are as follows:

SPECIES COMMON TO THE JAMES RIVER AND RAPPAHANNOCK SERIES NOT OCCURRING ABOVE.

Acrostichopteris parcelobata Font.
Anomozamites virginica Font.
Aspidium angustipinnatum Font.
dentatum Font.
Dunkeri (Schimp.) Font.
fredericksburgense Font.
parvifolium Font.
Athrotaxopsis expansa Font.
Baiera adiantifolia Font.
expansa Font.
Brachyphyllum parceramosum Font.
Cephalotaxopsis magnifolia Font.
microphylla Font.
Cladophlebis acuta Font.
brevipennis Font.
oblongifolia Font.
petiolata Font.
Cupressinoxylon Wardi Ku.
Cycadeospermum ellipticum Font.
obovatum Font.
Equisetum Lyelli Mant.
virginicum Font.
Nageiopsis heterophylla Font.
latifolia Font.
microphylla Font.
recurvata Font.
Pecopteris microdonta Font.
ovatodentata Font.
Proteæphyllum tenuinerve Font.
Rogersia longifolia Font.
Scleropteris elliptica Font.
virginica Font.
Sequoia Reichenbachi longifolia Font.
Sphenolepidium recurvifolium Font.
Sphenopteris thyrsopteroides Font.
Thyrsopteris dentata Font.
divaricata Font.
elliptica Font.
microloba alata Font.
nana Font.
obtusiloba Font.
rhombiloba Font.
squarrosa Font.
Zamites ovalis Font.

The Basal Potomac species that pass up into higher series may be considered with reference to whether they occur in the Mount Vernon Clays, in the Aquia Creek series, or in the Newer Potomac. The following is a list of 19 species that have their origin in the Basal Potomac and recur in the Mount Vernon Clays:

SPECIES PASSING UP FROM THE BASAL POTOMAC INTO THE MOUNT VERNON CLAYS.

Aspidium virginicum Font.
Cladophlebis constricta Font.
rotundata Font.
Ficophyllum tenninerve Font.
Gleichenia Nordenskiöldi Heer.
Glyptostrobus brookensis Font.
Myrica brookensis Font.
Nageiopsis angustifolia Font.
longifolia Font.
Proteæphyllum reniforme Font.
Rogersia angustifolia Font.
Sphenolepidium Sternbergianum (Dunk.) Heer.
Sphenopteris latiloba Font.
Thyrsopteris bella Font.
brevifolia Font.
decurrens Font.
rarinervis Font.
Zamites crassinervis Font.
tenninervis Font.

The following 15 species are common to the Mount Vernon and Aquia Creek series:

SPECIES COMMON TO THE MOUNT VERNON CLAYS AND THE AQUIA CREEK SERIES.

Aspidium virginicum Font.[1]
Baieropsis denticulata angustifolia Font.
Celastrophyllum Brittonianum Hollick?
Cladophlebis constricta Font.[1]
Glyptostrobus brookensis Font.[1]
Menispermites virginiensis Font.
Myrica brookensis Font.[1]
Nageiopsis angustifolia Font.[1]
Nageiopsis longifolia Font.[1]
Proteæphyllum reniforme Font.[1]
Rogersia angustifolia Font.[1]
Sphenopteris latiloba Font.[1]
Thyrsopteris bella Font.[1]
decurrens Font.[1]
rariuervis Font.[1]

Four species are found in both the Mount Vernon Clays and the Newer Potomac, as follows:

SPECIES COMMON TO THE MOUNT VERNON CLAYS AND THE NEWER POTOMAC.

Celastrophyllum Brittonianum Hollick?
Myrica brookensis Font.
Podozamites marginatus Heer.
Sphenopteris grevillioides Heer.

Only 6 Aquia Creek species, that is, species originating in the Aquia Creek series, are found in the Newer Potomac.

SPECIES COMMON AND CONFINED TO THE AQUIA CREEK SERIES AND THE NEWER POTOMAC.

Araliæphyllum acutilobum Font.
Celastrophyllum denticulatum Font.
latifolium Font.
Celastrophyllum robustum Newb.
undulatum Newb.
Populophyllum crassinerve Font.

Finally there are 6 species originating in the Basal Potomac which are also found in the Newer Potomac.

BASAL POTOMAC SPECIES PASSING UP INTO THE NEWER POTOMAC.

Cladophlebis parva Font.
Myrica brookensis Font.
Sequoia ambigua Heer.
Sequoia Reichenbachi (Gein.) Heer.
rigida Heer.
subulata Heer.

[1] Twelve of these, it will be seen, are common to this and the preceding list, i. e., they are species that pass up from the Basal Potomac through the Monnt Vernon beds into the Aquia Creek. There may therefore be said to be 6 Basal Potomac species that terminate in the Mount Vernon Clays, and 3 species that originate there.

The flora of the two localities which were treated as intermediate really shows that they belong to the Albirupean series, but may be somewhat lower than any of the other beds in that series. Eight of the species are confined to those localities, but there are 3 species not found in any of the higher beds which have their origin in the Older Potomac. They are the following:

OLDER POTOMAC SPECIES RECURRING IN THE LOWER ALBIRUPEAN AND NOT FOUND HIGHER.

Cladophlebis parva Font.
Populophyllum crassinerve Font.
Sequoia ambigua Heer.

There are 3 others that pass up from the Older Potomac and are found in both the Lower and Upper Albirupean, as follows:

OLDER POTOMAC SPECIES RECURRING IN THE LOWER ALBIRUPEAN AND ALSO FOUND HIGHER.

Celastrophyllum undulatum Newb.
Sequoia Reichenbachi (Gein.) Heer.
subulata Heer.

The last 5 lists embrace the 15 species of the Newer Potomac that have their origin in the Older Potomac, but as they recur in the different lists, and as this is one of the most important facts in the correlation, it seems best, at the risk of repetition, to reproduce this list by itself. The following are the species:

SPECIES COMMON TO THE OLDER AND NEWER POTOMAC.

Araliæphyllum acutilobum Font.
Celastrophyllum Brittonianum Hollick?
denticulatum Font.
latifolium Font.
robustum Newb.
undulatum Newb.
Cladophlebis parva Font.
Myrica brookensis Font.
Podozamites marginatus Heer.
Populophyllum crassinerve Font.
Sequoia ambigua Heer.
Reichenbachi (Gein.) Heer.
rigida Heer.
subulata Heer.
Sphenopteris grevillioides Heer.

These 15 species constitute the entire bond that unites the Older and Newer Potomac so far as species are concerned. That this bond may be strengthened by further discoveries is altogether probable, but it is especially desirable that plant-bearing beds be found and developed at intermediate horizons, such as are represented by the Iron Ore Clays.

The remaining 17 species are common to the Lower and Upper Albirupean and are not found at a lower horizon.

SPECIES OCCURRING IN THE LOWER AND UPPER ALBIRUPEAN AND NOT FOUND LOWER.

Andromeda latifolia Newb.
Asplenium Dicksonianum Heer.
Celastrophyllum crenatum Heer.
Chondrophyllum reticulatum Hollick.
Czekanowskia capillaris Newb.
Eucalyptus attenuata Newb.
parvifolia Newb.
Juniperus macilenta Heer.
Myrsine borealis Heer.
Podozamites sp. Hollick.
Proteoides daphnogenoides Heer.
Sassafras acutilobum Lx.
hastatum Newb.
rotundilobum Newb.
Sequoia gracillima (Lx.) Newb.
heterophylla Vel.
Tricalycites papyraceus Newb.

The following general table of distribution of the 140 species common to two or more of the great series of the Potomac formation will bring out the above relations in a somewhat more compact form:

Table of distribution of the species of Potomac plants occurring in two or more of the six primary subdivisions of the formation.

Species.	Older Potomac.				Newer Potomac.	
	Basal Potomac.			Middle Potomac.		
	James River.	Rappahannock.	Mount Vernon.	Aquia Creek.	Lower Albirupean.	Upper Albirupean.
Abietites angusticarpus Font	------	+	------	+	------	------
Acrostichopteris densifolia Font	+	------	------	?	------	------
parcelobata Font	+	+	------	------	------	------
parvifolia Font	+	------	------	?	------	------
Andromeda latifolia Newb	------	------	------	------	+	+
Anomozamites angustifolius Font	------	+	------	+	------	------
virginiens Font	+	+	------	------	------	------
Araliæphyllum acutilobum Font	------	------	------	+	------	?
Araucarites aquiensis Font	------	?	------	+	------	------
Aspidium angustipinnatum Font	+	+	------	------	------	------
dentatum Font	+	+	------	------	------	------
Dunkeri (Schimp) Font	+	+	------	------	------	------
ellipticum Font	------	+	------	+	------	------
fredericksburgense Font	+	+	------	------	------	------
parvifolium Font	+	+	------	------	------	------
virginicum Font	------	+	+	+	------	------
Asplenium Dicksoniauum Heer	------	------	------	------	+	+
Athrotaxopsis expansa Font	+	+	------	------	------	------
grandis Font	------	+	------	+	------	------
tenuicaulis Font	+	+	------	+	------	------
Baieropsis adiantifolia Font	+	+	------	------	------	------
denticulata angustifolia Font	------	------	+	+	------	------
expansa Font	+	+	------	------	------	------
Brachyphyllum crassicaule Font	+	------	------	+	------	------
parceramosum Font	+	?	------	------	------	------
Carpolithus brookensis Font	+	------	------	+	------	------
Celastrophyllum Brittonianum Hollick	------	------	?	?	------	+
crenatum Heer	------	------	------	------	+	+
denticulatum Font	------	------	------	+	------	+
latifolium Font	------	------	------	+	------	+
robustum Newb	------	------	------	?	------	+
undulatum Newb	------	------	------	+	+	+
Cephalotaxopsis magnifolia Font	+	+	------	------	------	------
microphylla Font	+	+	------	------	------	------
Chondrophyllum reticulatum Hollick	------	------	------	------	+	+
Cladophlebis acuta Font	+	+	------	------	------	------
brevipennis Font	+	+	------	------	------	------
constricta Font	------	+	?	+	------	------
crenata Font	------	+	------	+	------	------
oblongifolia Font	+	+	------	------	------	------
parva Font	------	+	------	------	+	------
petiolata Font	+	+	------	------	------	------
rotundata Font	------	+	?	------	------	------
? sp. Font	------	+	------	+	------	------
Cupressinoxylon Wardi Kn	+	+	------	------	------	------
Cycadeospermum ellipticum Font	+	+	------	------	------	------
obovatum Font	+	+	------	------	------	------

Table of the distribution of the species of Potomac plants, etc.—Continued.

Species.	Older Potomac.				Newer Potomac.	
	Basal Potomac.			Middle Potomac.		
	James River.	Rappahannock.	Mount Vernon.	Aquia Creek.	Lower Albirupean.	Upper Albirupean.
Czekanowskia capillaris Newb	------	------	------	------	?	+
Dioonites Buchianus (Ett.) Born	+	+	------	?	------	------
Equisetum Lyelli Mant	+	+	------	------	------	------
marylandicum Font	------	+	------	+	------	------
virginicum Font	+	?	------	------	------	------
Eucalyptus attennata Newb	------	------	------	------	+	+
parvifolia Newb	------	------	------	------	+	+
Ficophyllum crassinerve Font	+	+	------	+	------	------
serratum Font	------	+	------	+	------	------
tenulnerve Font	------	+	+	------	------	------
Gleichenia Nordenskiöldi Heer	+	+	+	------	------	------
Glyptostrobus brookensis Font	?	------	+	+	------	------
fastigiatus Font	------	+	------	+	------	------
Juniperus macilenta Heer	------	------	------	------	?	+
Leptostrobus longifolius Font	+	+	------	+	------	------
Menispermites virginiensis Font	------	------	+	+	------	------
Myrica brookensis Font	------	+	+	+	------	?
Myrsine borealis Heer	------	------	------	------	+	+
Nageiopsis angustifolia Font	+	+	?	+	------	------
crassicaulis Font	+	+	------	+	------	------
heterophylla Font	+	+	------	------	------	------
latifolia Font	+	+	------	------	------	------
longifolia Font	+	+	+	+	------	------
microphylla Font	+	+	------	------	------	------
recurvata Font	+	+	------	------	------	------
zamioides Font	+	+	------	+	------	------
Pecopteris Browniana Dunk	+	+	------	?	------	------
microdonta Font	+	+	------	------	------	------
ovatodentata Font	+	+	------	------	------	------
strictinervis Font	------	+	------	?	------	------
virginiensis Font	+	+	------	+	------	------
Podozamites acutifolius Font	+	+	------	+	------	------
distantinervis Font	+	+	------	?	------	------
marginatus Heer	------	------	?	------	------	?
pedicellatus Font	------	+	------	?	------	------
sp. Hollick	------	------	------	------	+	+
Populophyllum crassinerve Font	------	------	------	+	+	------
Proteæphyllum reniforme Font	------	+	+	+	------	------
tenninerve Font	+	+	------	------	------	------
Proteoides daphnogenoides Heer	------	------	------	------	+	+
Rogersia angustifolia Font	------	+	+	+	------	------
longifolia Font	+	+	------	------	------	------
Sagenopteris elliptica Font	+	+	------	?	------	------
Saliciphyllum ellipticum Font	+	+	------	+	------	------
Sassafras acutilobum Lx	------	------	------	------	+	+
hastatum Newb	------	------	------	------	+	+
(Araliopsis) rotundilobum Newb	------	------	------	------	+	+
Scleropteris elliptica Font	+	+	------	------	------	------
virginica Font	+	+	------	------	------	------
Sequoia ambigua Heer	+	------	------	------	?	------
gracillima (Lx.) Newb	------	------	------	------	+	+
heterophylla Vel	------	------	------	------	+	+
Reichenbachi (Gein.) Heer	+	+	------	+	+	+
longifolia Font	+	+	------	------	------	------

Table of distribution of the species of Potomac plants, etc.—Continued.

Species.	Older Potomac.				Newer Potomac.	
	Basal Potomac.			Middle Potomac.		
	James River.	Rappahannock.	Mount Vernon.	Aquia Creek.	Lower Albirupean.	Upper Albirupean.
Sequoia rigida Heer	+	+	.....	.....	.....	+
subulata Heer	+	+	.....	.....	+	+
? sp. Font	.....	+	.....	+	.....	.....
Sphenolepidium Kurrianum (Dunk.) Heer	+	.....	.....	+	.....	.....
parceramosum Font	.....	+	.....	+	.....	.....
recurvifolium Font	+	+	.....	.....	.....	.....
Sternbergianum (Dunk.) Heer	.....	+	+	.....	.....	.....
Sternbergianum densifolium Font	+	+	.....	+	.....	.....
virginicum Font	.....	+	.....	+	.....	.....
Sphenopteris acrodentata Font	+	.....	.....	?		.....
grevillioides Heer	.....	.....	+	.....	.....	+
latiloba Font	+	+	?	+	.....	.....
thyrsopteroides Font	+	+	.....	.....	.....	.....
Thinnfeldia variabilis Font	.....	+	.....	+	.....	.....
Thyrsopteris angustifolia Font	+	+	.....	+	.....	.....
angustiloba Font	+	+	.....	+	.....	.....
bella Font	+	+	+	+	.....	.....
brevifolia Font	+	.....	+	.....	.....	.....
brevipennis Font	+	.....	.....	+	.....	.....
decurrens Font	+	+	+	+	.....	.....
densifolia Font	.....	+	.....	+	.....	.....
dentata Font	+	+	.....	.....	.....	.....
divaricata Font	+	+	.....	.....	.....	.....
elliptica Font	+	+	.....	.....	.....	.....
Meekiana Font	+	+	.....	+	.....	.....
angustiloba Font	+	+	.....	+	.....	.....
microloba alata Font	+	+	.....	.....	.....	.....
nana Font	+	+	.....	.....	.....	.....
obtusiloba Font	+	+	.....	.....	.....	.....
pachyrachis Font	+	+	.....	?	.....	.....
rarinervis Font	+	+	+	+	.....	.....
rhombifolia Font	.....	+	.....	?	.....	.....
rhombiloba Font	+	+	.....	.....	.....	.....
squarrosa Font	+	+	.....	.....	.....	.....
Tricalycites papyraceus Newb	.....	.....	.....	.....	+	+
Zamiopsis petiolata Font	.....	+	.....	?	.....	.....
Zamites crassinervis Font	.....	+	?	.....	.....	.....
ovalis Font	+	+	.....	.....	.....	.....
tenuinervis Font	+	+	+	.....	.....	.....

In this table I have not separated the Island series from the rest of the Upper Albirupean, because, as already stated, the great similarity in the flora scarcely seems to warrant this. To show this more clearly I introduce here the following list of 52 species common to the Island series and other localities in the Upper Albirupean:

Acer amboyensis Newb.
Andromeda Novæ-Cæsareæ Hollick.
Parlatorii Heer.
Aralia patens Newb.
Asplenium Dicksonianum Heer.
Celastrophyllum grandifolium Newb.
undulatum Newb.
Cissites formosus Heer.
Colutea primordialis Heer.
Dammara borealis Heer.
Diospyros primæva Heer.
rotundifolia Lx.
Eucalyptus attenuata Newb.
Geinitzi Heer.
nervosa Newb.
Ficus atavina Heer.
Woolsoni Newb.
Hymenæa dakotana Lx.
Juglans arctica Heer.
crassipes Heer.
Laurophyllum lanceolatum Newb.
Laurus Plutonia Heer.
Liriodendron oblongifolium Newb.
Liriodendropsis angustifolia Newb.
simplex Lx.
Magnolia auriculata Newb.
Magnolia Capellinii Heer.
glaucoides Newb.
longifolia Newb.
longipes Newb.
speciosa Heer.
Myrica brookensis Font.
Hollicki Ward.
Newberryana Hollick.
Myrisine elongata Hollick.
Phyllites poinsettioides Hollick.
Populus? apiculata Newb.
Proteoides daphnogenoides Heer.
Salix proteæfolia Lx.
Sapindus Morrisii Lx.
Sassafras acutilobum Lx.
progenitor Newb.
rotundilobum Newb.
Sequoia ambigua Heer.
gracillima (Lx.) Newb.
heterophylla Vel.
Reichenbachi (Gein.) Heer.
Thinnfeldia Lesquereuxiana Heer.
Tricalycites papyraceus Newb.
Viburnum integrifolium Newb.
Widdringtonites Reichii (Ett.) Heer.
Williamsonia problematica Newb.

BOTANICAL CHARACTERS OF THE POTOMAC FLORA.

Thus far we have considered the Potomac formation as a whole without reference to botanical classification. This aspect of the subject may now be taken into account. It may be said in general that the flora consists chiefly of ferns, cycads, conifers, and dicotyledons. Only three cellular cryptogams have been described, all of which are more or less doubtful from the imperfect condition of their preservation. The genus Equisetum is represented by 7 species, not all of which are well defined. One species has been referred to the genus Casuarina, and 7 different forms, some of them with more or less doubt, to the monocotyledons, 2 of the latter being supposed to be palms. Besides these there are 39 forms whose botanical affinities can not be determined, 25 of which consist of fruits and seeds which have been grouped together under the general name of Carpolithus and which can not now be referred, with any certainty, to their respective genera. Leaving all of these out of the account, we find the ferns represented by 31 genera and 161 species, constituting nearly 22 per cent of the total flora; the Cycadaceæ by 14 genera and 44 species, or 6 per cent of the

flora; the Coniferæ by 34 genera and 146 species, or nearly 20 per cent of the flora; and the dicotyledons by 92 genera and 330 species, or slightly less than 45 per cent of the flora.

Most of the genera of ferns are represented by only a few species, and the greater number of the species belong to the following 7 genera: Angiopteridium 9 species, Aspidium 14 species, Cladophlebis 22 species, Ctenopteris 6 species, Pecopteris 10 species, Sphenopteris 7 species, and Thyrsopteris 40 species. In all but 2 of these genera the species are confined to the Older Potomac. All the species of Angiopteridium come from the Rappahannock series. Three species of Aspidium occur in the Aquia Creek series, 1 in the Mount Vernon Clays, and the rest are about equally distributed between the two basal series. Cladophlebis belongs chiefly to the Basal Potomac, but 2 species occur in the Mount Vernon Clays, 3 in the Aquia Creek series, and 1 species, *C. parva* Font., is represented in the collection from Snow's plantation, which I have considered as belonging to the Lower Albirupean. This is originally a Rappahannock species, but it is also found in the Kootanie. The 6 species of Ctenopteris are all confined to the Rappahannock series. All the forms that have been united with the Paleozoic species Pecopteris are found in the Older Potomac, and 4 pass up into the Aquia Creek series. Only 2 of the 8 species of Sphenopteris occur in the Newer Potomac, and both of these are involved in some doubt. *S. latiloba* Font. is the most common and is found in all four of the Older Potomac series.

The genus Thyrsopteris has the greatest interest of all the genera of ferns, and in many respects may be regarded as the most important genus of the Potomac formation. It is a living genus, but is represented by only a single species, *T. elegans* Kunze, which is confined to the island of Juan Fernandez. It is closely related to Cyathea, and somewhat less closely to Dicksonia. In studying the extensive material from the Jurassic of Siberia, Professor Heer encountered a large number of specimens which he was unable to refer to any of the previously described fossil genera, and upon a very careful examination he found these forms to agree so exactly with the living genus Thyrsopteris that he was compelled to refer them to that genus. Brongniart had already pointed out the resemblance of his *Pecopteris Murrayana* from the Oolite of Yorkshire to this living genus, and had united this species with others into a distinct genus, Coniopteris, to which Saporta afterwards referred a number of species from the Jurassic of France. It is therefore very probable that the genus Thyrsopteris, which is now so nearly extinct, was widely distributed over the northern hemisphere in Jurassic time. We have in America no true Jurassic flora thus far, but should such a flora hereafter come to light there can scarcely be any doubt that this genus will be found in it. At all events, the most abundant type of fern that exists in our Older Potomac flora is so closely related to the Jurassic forms classed as Thyrsopteris that it

was impossible for Professor Fontaine to separate them. Out of the great mass of material of this class collected by him, chiefly in the James River and Rappahannock series, he distinguished no less than 40 species. There may be grave doubts as to whether so large a number of species should have been made, but the characters are tolerably distinct, and should it be necessary in the future to combine some of these this will be much easier than it would be to separate species that had been injudiciously united. Of these 40 species 12 occur in the Aquia Creek series, only 1 of which, *T. distans* Font., is confined to that horizon, all the rest occurring in the Older Potomac also. Four species have been detected in the Mount Vernon Clays, but none of them is confined to these beds. Three of these species, *T. bella* Font., *T. decurrens* Font., and *T. rarinervis* Font., are found in all four of the Older Potomac series. Taking out all these cases there remain 27 species of Thyrsopteris which are confined to the Basal Potomac. Eight of these occur in both of the Basal members, 2 are confined to the James River, and 17 to the Rappahannock series.

The most important cycadaceous genera are Dioonites, Podozamites, Williamsonia, and Zamites. These, with the exception of the Podozamites, are all confined to the Older, and chiefly to the Basal, Potomac. The *Dioonites Buchianus* (Ett.) Born. is important, mainly, for its great abundance in the lowest beds known. It seems to have gradually grown rarer before the close of the James River period, and is a somewhat rare plant in the Rappahannock series. Its occurrence even in the Aquia Creek series is doubtful. It and its varieties are characteristic James River forms in the sense that they are almost always found wherever there are any plants at that horizon, while at any higher level they are to be met with only when the collections are large. The genus Podozamites is the largest of the Cycadaceæ, being represented by 12 species. Five are Basal Potomac species, 2 of which, however, pass up into the Aquia Creek series. In the Newer Potomac a number of forms have been found which must be referred for the present to that genus. They consist entirely of fragments of leaves too imperfect in most cases for safe specific determination. One has been referred to *P. tenuinervis* Heer, and another to *P. marginatus* Heer. The Mount Vernon Clays contain some well-preserved leaves of Podozamites. To the genus Williamsonia 6 forms have been referred, to only 4 of which specific names have been given. One of these, *W. virginiensis* Font., is confined to the James River beds, where it is not rare. The other 3 are confined to the Amboy Clays, and 1 of them is the plant that Dr. Newberry at first supposed to be a fossil sunflower and named *Palæanthus problematicus*. One of the undescribed forms was collected by Mr. White at Gay Head, and the other is from Alabama. I shall, for the present at least, treat this type as cycadean. To the genus Zamites belong 7 distinct forms, all from the Older Potomac, and none of them found in the Aquia Creek series. But in the Mount Vernon

series *Z. crassinervis* Font. and *Z. tenuinervis* Font. have both been detected, and there is another well-preserved leaf that does not belong to either of these species. I have already dwelt sufficiently upon the forms that I call *Zamia Washingtoniana* (see supra, p. 350, and Pl. II, Fig. 6). On the whole, then, the Cycadaceæ of the Potomac formation are found to be almost exclusively Older Potomac and chiefly Basal Potomac, while in this order we have the most characteristic species of the James River series, or oldest known Potomac beds. The cycadean trunks of Maryland, referable to the genus Cycadeoidea, and of which a large number of specimens have recently been collected by Mr. Arthur Bibbins, probably belong with the leaves of one or other of the above-mentioned genera.

The Coniferæ, with their 146 species, constitute a very important group of plants for the Potomac formation. The largest genera are: Athrotaxopsis 6 species, Baieropsis 10 species, Brachyphyllum 8 species, Glyptostrobus 8 species, Leptostrobus 7 species, Nageiopsis 14 species, Pinus 9 species, Sequoia 22 species, and Sphenolepidium 8 species. The most interesting of these is Professor Fontaine's new genus Nageiopsis, so closely resembling a cycad, but which he regards as nearly related to the section Nageia of the living genus Podocarpus. This genus is exclusively confined to the Older Potomac. It is well represented in the James River series, but has 4 species that pass up into the Aquia Creek series. Two of these, *N. angustifolia* Font. and *N. longifolia* Font., are found in the intermediate Mount Vernon Clays. The genus may perhaps be regarded as having its highest development in the Rappahannock series. The genus Sequoia, though the largest of Potomac conifers, is so widely distributed throughout all the Cretaceous and Tertiary deposits over nearly the whole globe, still persisting on the Pacific Coast in 2 species, that its value as a genus is not specially important. In fact, it is one of the few genera which occur in every one of the 6 subdivisions of the Potomac formation here made, and one species, *S. Reichenbachi* (Gein.) Heer, is found in all of them except the Mount Vernon Clays. The great quantity of silicified wood found especially in the Rappahannock sands and referred to Cupressinoxylon really belongs without doubt to the genus Sequoia, and the trees that were thus petrified probably bore the leaves and cones of several of the species of that genus that are enumerated. Sphenolepidium is an exclusively Older Potomac genus, but 4 of its 8 species occur in the Aquia Creek series, though none of them are confined to it. It may be regarded as mainly a Rappahannock type.

Just as the ferns and cycads are chiefly confined to the Older Potomac, so the dicotyledons are in the main represented in the Newer Potomac. Still, there are a number of genera somewhat abundant in the Rappahannock, and found even in the James River series, whose leaves exhibit a peculiar nervation, which I have characterized as archaic.[1] Such are

[1] Am. Jour. Sci., 3d ser., Vol. XXXVI, August, 1888, p. 120.

the Aristolochiæphyllum, Ficophyllum, Proteæphyllum, Quercophyllum, Rogersia, Saliciphyllum, and Vitiphyllum. Celastrophyllum enjoys the distinction of being represented throughout the entire Potomac formation, being found in all its plant-bearing subdivisions, and it also has a special value as indicating a gradual transition in its varied forms from the lowest to the highest beds. Professor Fontaine's Rogersia seems without doubt to be the Older Potomac representative and true lineal ancestor of the forms which Dr. Newberry refers to Eucalyptus, and taking these two together we have almost as complete a series as that which Celastrophyllum presents. A somewhat shorter series may also be made out by combining the Sapindopsis of Fontaine, which begins in the Rappahannock series, with the Fontainea of Newberry from the lowest Raritan beds of Woodbridge, N. J., also found at Round Bay, on the Severn River, Maryland. Many other similar lines of development might even now be traced, but when all the material of this class is carefully elaborated, this branch of the investigation will become an exceedingly hopeful one.

The following table will show the numerical relations that subsist among the different types of vegetation represented in the Potomac flora:

Types of vegetation.	Genera.	Species.	Species to a genus.	Per cent of genera.	Per cent of species.
Cellular Cryptogams	2	2	1	1	.3
Ferns	31	160	5.2	15.7	21.7
Equisetaceæ	1	7	7	.5	.9
Cycadaceæ	14	44	3.1	7.1	6
Coniferæ	34	146	4.3	17.2	19.8
Casuarinaceæ	1	1	1	.5	.1
Monocotyledons	8	8	1	4	1
Dicotyledous	92	330	3.6	46.7	44.8
Of unknown affinities	15	39	2.6	7.6	5.3
Total	198	737	3.7	.....	.....

GEOGRAPHICAL AND GEOLOGICAL DISTRIBUTION OF THE POTOMAC FLORA.

Thus far attention has been restricted entirely to the internal relations of the Potomac flora with a view to the correlation by means of fossil plants of the several subordinate floras or florulas corresponding to the stratigraphical subdivisions treated in the first part of this paper. It is now proposed to consider briefly the external relations of the Potomac flora, that is to say, the geographical and geological range that it has outside of the Potomac terrane.

It was seen in discussing the internal relations that of the 737 species which make up the Potomac flora only 140 occur at more than one of the six horizons into which the formation was divided. Similarly, in discussing the external relations we now find that only 176 species have a distribution outside of the Potomac formation proper. These may be divided into two distinct classes:

First, species that were named from other parts of the world before investigations into the Potomac formation had been instituted, chiefly at horizons not widely differing from some of those of the Potomac, and which have subsequently been discovered in the Potomac formation. Of such species 141 are enumerated.

Second, species that were first described and named from the Potomac formation and have since been found at other localities. Of species belonging to this class 35 have thus far occurred. It so happens that these latter are all species named by Professor Fontaine from the Older Potomac and have been found, chiefly by him, in collections from other Lower Cretaceous deposits in the United States.

These two classes will be considered separately in the order named.

DISTRIBUTION OF FOREIGN SPECIES.

As a basis for such remarks as it may be thought best to make upon the plants of this class, the following table of distribution of the 142 species representing it may best be introduced at this point:

Table of distribution of the species of fossil plants identified in the Potomac formation but previously described from other localities and horizons.

Species.	James River.	Rappahannock.	Mount Vernon.	Aquia Creek.	Lower Albirupean.	Upper Albirupean.	Jurassic.	Wealden.	Trinity.	Black Hills.	Kootanie.	Shasta.	Cape Lisburn, Alaska.	Neocomian, Europe.	Urgonian, Kome, Greenland.	Gault, Europe and Spitzbergen.	Atane beds, Greenland.	Dakota formation.	Upper Kanab Valley.	Mill Creek series, Canada.	Cenomanian, Europe.	Patoot, Greenland.	Canada and British Columbia.	Senonian, Europe.	Laramie formation.	Post Laramie (Denver, etc.).	Fort Union.	Arctic Tertiary (Eocene?).	Green River group.	Paleocene (Sézanne, Gelinden).	Eocene, Europe.	Oligocene, Europe.	Miocene, Europe.
	Potomac formation.						Other localities and horizons.																										
								Lower Cretaceous.									Upper Cretaceous.											Tertiary.					
Andromeda Parlatorii Heer						+											+	+															
Pfaffiana Heer						+											+	+															
Aralia formosa Heer						+												+			+												
grönlandica Heer						+											+	+															
quinquepartita Lx						+												+															
transversinervia Sap. & Mar						+																								+	+		
Wellingtoniana Lx						+												+															
Aristolochites dentatus Heer			?															+															
Aspidium Dunkeri (Schimp.) Font	+	+						+				?		+																			
Oerstedi Heer	+												+				+					+											
Asplenium Dicksonianum Heer					+	+				+	+		+		+		+	+															
Foersteri Deb. & Ett						+											+				+			+									
Baiera longifolia (Pom.) Heer	+						+				+																						
Brachyphyllum crassum Lx						+												+	+														
Celastrophyllum Benedeni Sap. & Mar						+																								+			
crenatum Heer					+	+																+											
cretaceum Lx						+												+															
decurrens Lx						?												+															
obtusum Heer						?											+																
Celastrus arctica Heer						+																+											
Chondrophyllum orbiculatum Heer						+											+																
Cinnamomum Heerii Lx						+												+					+										
Marioni Lx						?												+															
sezannense Wat						+											+					+								+	+		
Cissites crispus Vel						+															+												
formosus Heer						+											+	+															
Colutea primordialis Heer						+											+	+															
Cratægus subtilis Heer						?																						+					
Cunninghamites elegans (Corda) Endl						+		+													+	+		+									

Table of distribution of the species of fossil plants identified in the Potomac formation, etc.—Continued.

Species.	Potomac formation.						Other localities and horizons.																										
								Lower Cretaceous.									Upper Cretaceous.											Tertiary.					
	James River.	Rappahannock.	Mount Vernon.	Aquia Creek.	Lower Albirupean.	Upper Albirupean.	Jurassic.	Wealden.	Trinity.	Black Hills.	Kootanie.	Shasta.	Cape Lisburn, Alaska.	Neocomian, Europe.	Urgonian, Kome, Greenland.	Gault, Europe and Spitzbergen.	Atane beds, Greenland.	Dakota formation.	Upper Kanab Valley.	Mill Creek series, Canada.	Cenomanian, Europe.	Patoot, Greenland.	Canada and British Columbia.	Senonian, Europe.	Laramie formation.	Post Laramie (Denver, etc.).	Fort Union.	Arctic Tertiary (Eocene?).	Green River group.	Paleocene (Sézanne, Gelinden).	Eocene, Europe.	Oligocene, Europe.	Miocene, Europe.
Cyathea fertilis Heer						?											+																
Dalbergia hyperborea Heer						+											+																
Rinkiana Heer						+											+																
Dammara borealis Heer						+											+				+												
microlepis Heer						+											+																
Daphnophyllum dakotense Lx						?												+															
Dewalquea grönlandica Heer						+											+					+											
haldemiana (Deb.) Sap. & Mar						?													+			+		+									
insignis Hos. & Marck						+											+					+		+									
Dioonites Buchianus (Ett.) Born	+	+		?				+	+																								
Diospyros primæva Heer						+											+	+			+	+											
rotundifolia Lx						+												+															
Steenstrupi Heer						+																+											
Equisetum Lyelli Mant	+	+						+																									
Eucalyptus Geinitzi Heer						+											+	+			+												
Eugenia primæva Lx						?												+															
Ficus atavina Heer						+											+		+			+											
inæqualis Lx						+												+															
lanceolata Heer						?																			+	+			+		+		+
lanceolato-acuminata Ett						+												+														+	
protogæa Heer						?											+							+									
Frenelopsis Hoheneggeri (Ett.) Schenk						?	+	+	+						+																		
Geinitzia formosa Heer						?															+												
Gleichenia Giesekiana Heer						?									+		+					+											
gracilis Heer						+									+		+				+												
micromera Heer						+									+																		
Nordenskiöldi Heer	+	+	+												+			+															
Zippei (Corda) Heer						+				+					+	+	+				+	+		+									
Grewiopsis viburnifolia Ward						?																					+						
Hedera primordialis Sap						+											+				+												
Hymenæa Dakotana Lx						+												+															
Ilex Masoni Lx						+												+															

Table of distribution of the species of fossil plants identified in the Potomac formation, etc.—Continued.

Species.	Potomac formation.						Other localities and horizons.	Lower Cretaceous.									Upper Cretaceous.											Tertiary.					
	James River.	Rappahannock.	Mount Vernon.	Aquia Creek.	Lower Albirupean.	Upper Albirupean.	Jurassic.	Wealden.	Trinity.	Black Hills.	Kootanie.	Shasta.	Cape Lisburn, Alaska.	Neocomian, Europe.	Urgonian, Kome, Greenland.	Gault, Europe and Spitzbergen.	Atane beds, Greenland.	Dakota formation.	Upper Kanab Valley.	Mill Creek series, Canada.	Cenomanian, Europe.	Patoot, Greenland.	Canada and British Columbia.	Senonian, Europe.	Laramie formation.	Post Laramie (Denver, etc.).	Fort Union.	Arctic Tertiary (Eocene?).	Green River group.	Paleocene (Sézanne, Gelinden).	Eocene, Europe.	Oligocene, Europe.	Miocene, Europe.
Juglans arctica Heer	...	...	...	...	...	?	...	...	...	...	...	...	...	...	...	...	+	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
crassipes Heer	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	+	...	...	+	+	...	...	...	...	...	...	...	...	...	...	...
Juniperus hypnoides Heer	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...
macilenta Heer	...	...	...	...	?	+	...	...	...	...	...	...	...	...	...	...	+	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...
Laurophyllum ellsworthianum Lx	...	...	...	...	...	?	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Laurus Hollæ Heer	...	...	...	...	...	?	...	...	...	...	...	...	...	...	...	...	+	+	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...
Omalii Sap. & Mar	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...
plutonia Heer	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	+	+	...	...	+	+	...	...	...	...	...	...	...	...	...	...	...
præstans Lx	...	...	...	...	...	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...
Leguminosites atanensis Heer	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
constrictus Lx	...	...	...	...	...	?	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
convolutus Lx	...	...	...	...	...	?	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
frigidus Heer	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...
omphalobioides Lx	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Magnolia alternans Heer	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	+	+	...	...	+	...	...	...	+	...	...	...	...	...	...	...	...
Capellinii Heer	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	+	+	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...
Isbergiana Heer	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Lacoeana Lx	...	...	...	...	...	?	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
speciosa Heer	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	+	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...
Majanthemophyllum pusillum Heer	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...
Menispermites borealis Heer	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Microzamia gibba (Reuss) Corda	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	+	...	...	...	...	...	...	...	...	...
Moriconia cyclotoxon Deb. & Ett	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	+	...	+	...	...	...	...	...	...	...	...	...
Myrica emarginata Heer	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	+	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
longa Heer	...	...	...	...	...	?	...	...	...	...	...	...	...	...	...	...	+	+	...	...	+	+	+	...	...	...	...	...	...	...	...	...	...
parvula Heer	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...
Myrsine borealis Heer	...	...	...	...	+	+	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Nyssa Snowiana Lx	...	...	...	...	...	?	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Ophioglossum granulatum Heer	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...
Osmunda Obergiana Heer	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Paliurus affinis Heer	...	...	...	...	...	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...
ovalis Dn	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	+	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...

Table of distribution of the species of fossil plants identified in the Potomac formation, etc.—Continued.

Species.	Potomac formation.						Other localities and horizons.																										
								Lower Cretaceous.									Upper Cretaceous.											Tertiary.					
	James River.	Rappahannock.	Mount Vernon.	Aquia Creek.	Lower Albirupean.	Upper Albirupean.	Jurassic.	Wealden.	Trinity.	Black Hills.	Kootanie.	Shasta.	Cape Lisburn, Alaska.	Neocomian, Europe.	Urgonian, Kome, Greenland.	Gault, Europe and Spitzbergen.	Atane beds, Greenland.	Dakota formation.	Upper Kanab Valley.	Mill Creek series, Canada.	Cenomanian, Europe.	Patoot, Greenland.	Canada and British Columbia.	Senonian, Europe.	Laramie formation.	Post Laramie (Denver, etc.).	Fort Union.	Arctic Tertiary (Eocene?).	Green River group.	Paleocene (Sézanne, Gelinden).	Eocene, Europe.	Oligocene, Europe.	Miocene, Europe.
Pecopteris Browniana Dunk	+	+		?			+	+			+			+																			
socialis Heer				+													+																
Persea nebrascensis Lx						+												+															
Phegopteris Grotheana Heer						?																+											
Phyllites amissus Lx						?												+															
durescens Lx						?												+															
Vanonæ Heer						?												+															
Platanus Heerii Lx						+											+	+		+													
Newberryana Heer						+												+				+											
Podozamites angustifolius (Eichw.) Schimp						+	+											+															
marginatus Heer			?			?											+																
tenuinervis Heer						+											+																
Populites elegans Lx						?												+															
Populus hyperborea Heer						?											+	+															
Proteoides daphnogeneides Heer					+	+												+		+													
Protophyllum præstans Lx					?													+															
undulatum Lx					?													+															
Pterospermites longeacuminatus Lx						?												+															
modestus Lx						+												+															
Quercus Johnstrupi Heer						+																+											
Rhamnus inæquilateralis Lx						?												+															
Pfaffiana Heer						+																+											
Salix proteæfolia Lx						+												+															
flexuosa Lx						?												+															
Raeana Heer						?																			+			+					+
Sapindus Morrisoni Lx						+											+	+				+											
Sapotacites retusus Heer						+																+											
Sassafras acutilobum Lx					+	+												+			+												
Sequoia ambigua Heer	+				?										+		+																
condita Lx						+												+															
gracillima (Lx.) Newb					+	+												+		+			+										
gracilis Heer				+							+				+																		

Table of distribution of the species of fossil plants identified in the Potomac formation, etc.—Continued.

Species.	Potomac formation.						Other localities and horizons.																																	
							Lower Cretaceous.											Upper Cretaceous.									Tertiary.														
	James River.	Rappahannock.	Mount Vernon.	Aquia Creek.	Lower Albirupean.	Upper Albirupean.	Jurassic.	Wealden.	Trinity.	Black Hills.	Kootanie.	Shasta.	Cape Lisburne, Alaska.	Neocomian, Europe.	Urgonian, Kome, Greenland.	Gault, Europe and Spitzbergen.	Atane beds, Greenland.	Dakota formation.	Upper Kanab Valley.	Mill Creek series, Canada.	Cenomanian, Europe.	Patoot, Greenland.	Canada and British Columbia.	Senonian, Europe.	Laramie formation.	Post Laramie (Denver, etc.).	Fort Union.	Arctic Tertiary (Eocene?).	Green River group.	Palæocene (Sézanne, Gelinden).	Eocene, Europe.	Oligocene, Europe.	Miocene, Europe.
Sequoia beterophylla Vel						+					+					+	+				+			+															
Reichenbachi (Germ.) Heer	+	+		+		+					+					+	+				+		+	+															
rigida Heer	+	+				+					+					+																							
Smittiana Heer						+																																	
subulata Heer	+	+			+																																		
Sphenolepidium Kurrianum (Dunk.) Hr	+			+			+	+						+			+																						
Sternbergianum (Dunk.) Heer		+	+				+	+						+																									
Sphenopteris grevillioides Heer			+												+																								
Mantelli Brongn				?		+	+	+				+		+				+			+																		
Stercnlia Snowii Lx						+											+																						
Thinnfeldia Lesquereuxiana Heer						+											+																						
Thuya cretacea (Heer) Newb						+									+		+																						
Thuyites Meriani Heer						+											+																						
Viburnum inæquilaterale Lx						+																																	
Widdringtonites Reichii (Ett.) Heer						+											+																						
subtilis Heer																																							

It will be seen from this table that although there are species which have a foreign distribution, in the sense explained, from each of the six subdivisions of the Potomac formation, the great bulk of them belong to the Newer Potomac, and chiefly, of course, to the Amboy Clay flora. It will also be observed, in harmony with the last remark, that although in such foreign distribution there is a range extending from the Jurassic to the Miocene, still, by far the greater part of the species thus compared were originally described from the Cretaceous, and especially from the Middle Cretaceous. The particular group that has yielded the largest number of such species is that known as the Atane beds of Greenland, correlated by Heer and other authors with the Cenomanian of Europe. Next to this comes the Patoot beds of Greenland, occupying a higher horizon, and correlated by common consent with the Senonian of Europe.

The whole number of species common to the Potomac and the Atane beds is 56, 10 of which, however, have their identity somewhat in doubt, as indicated by the query mark in the Potomac column. Most of these cases are probably correct, and where they do not exactly correspond they no doubt indicate a close genetic relationship. On the general theory that the Lower Cretaceous once extended around the entire Atlantic border, but that north of Massachusetts the sea has encroached upon it so as to cut it away entirely, its recurrence in Greenland, in the position of the Kome and Atane beds, is a perfectly natural circumstance. The channel which separates Greenland from the next land to the west has in like manner cut away the older portion of the formation, and left for the most part only the later Cretaceous deposits. These were probably also present in some parts of the United States, where they are now buried deeply beneath still later marine deposits. The Kome beds of Greenland, however, actually represent a horizon corresponding to the Older Potomac, and, as will be seen by this table, they contain a number of species which have been identified in the latter. It is not absolutely impossible, either, that the highest beds of the Newer Potomac, as for example those of Long Island and Gay Head, may be nearly or quite as high as the Atane beds themselves, and it is doubtful whether there is sufficient evidence outside of the fossil plants to prove that the Atane beds are properly to be classed in the Upper rather than in the Lower Cretaceous. Be this as it may, the 46 well-authenticated species that are common to the two have a strong bearing as establishing their close geological synchronism. Nor is it to be wondered at that a considerable number of species should be common to the Newer Potomac and the Patoot beds. There are 31 such species, but the greater part of them also occur in the Atane beds; that is, they are species which have passed up from the Lower into the Upper Cretaceous in the same restricted geographical position.

Quite a large number of these species, about 25, were originally found in the Middle Cretaceous or Cenomanian of Europe, and have been identified with more or less certainty in the Newer Potomac. A considerable number of these are also common to the Atane beds, and some have a wide distribution.

The most important fact brought out in this table, and the one which most needs to be commented upon and explained, as liable to lead to erroneous conclusions, is the very large number of species that would seem upon the face to be common to the Newer Potomac and the Dakota formation. There are no less than 66 such cases, or 10 more than were noted for the Atane beds. No better illustration could be found of the imperfection of such tabular statements for setting forth the true state of things under such conditions as we have before us. A very little analysis will show how entirely deceptive this fact is. For example, a casual glance at the table shows that of these Dakota species 19 are also common to the Atane beds. They are species described by Heer and afterwards identified by Lesquereux as also occurring in the Dakota. As is now well known, many of these identifications will require revision. In most cases there are differences enough to indicate that considerable change at least had taken place in the species before their reappearance in Dakota time, and in several cases this difference is doubtless specific. But even if we were to admit that the identifications were all correct, it would still not be true in any of these 19 cases that properly Dakota species had been found in the Amboy Clays, but only that so many Atane species are found in both the Amboy Clays and in the Dakota group.

If now we glance at the Newer Potomac columns we find that still another 19 species are introduced into those columns with marks of interrogation, which means that Dr. Newberry and Dr. Hollick were in doubt as to their identification with Dakota species. A few of these cases will doubtless stand, but in most of them, when additional material shall have been collected, it will probably be found that they are only more or less closely related to the Western forms. There are several other cases of such wide distribution as to have no significance from this point of view. When, therefore, we sift the matter to its essential elements, we find that there are really only 18 bona fide cases in which Dakota species have been identified in the Amboy Clays or their equivalent. These 18 species are the following:

Aralia quinquepartita Lx.
Wellingtoniana Lx.
Brachyphyllum crassum Lx.
Celastrophyllum cretaceum Lx.
Cinnamomum Heerii Lx.
Diospyros rotundifolia Lx.
Ficus inæqualis Lx.
Hymenæa dakotana Lx.
Ilex Masoni Lx.
Leguminosites omphalobioides Lx.
Persea nebrascensis Lx.
Proteoides daphnogenoides Heer.
Pterospermites modestus Lx.
Salix proteæfolia Lx.
Sassafras acutilobum Lx.
Sequoia condita Lx.
gracilis (Lx.) Newb.
Viburnum inæquilaterale Lx.

All but 4 of these 18 species are, so far as now known, confined to the Dakota group and the Newer Potomac. *Brachyphyllum crassum* Lx. was first described from the Upper Kanab Valley in Utah, where a considerable collection was once made, but the age of which has never been definitely fixed. In it Professor Lesquereux also identified the *Dewalquea haldemiana* (Deb.) Sap. and Mar., a plant from the Senonian of Europe which recurs in the Patoot beds of Greenland, and *Ficus atavina* Heer from the Atane and Patoot beds. *Cinnamomum Heerii* Lx. is believed to have been found in the Nanaimo beds on Vancouver Island, also on Orcas Island, both of which are regarded as Upper Cretaceous. Its supposed occurrence at the locality on Bellingham Bay is one of the facts which put the horizon of that locality in doubt. *Proteoides daphnogenoides* Heer has been detected by Dawson in the Mill Creek series of Canada. *Sassafras acutilobum* Lx., the only other species that has a distribution outside of the Dakota formation and Amboy Clays, is one of the best-known Dakota species, and has been identified by Velenovský in the Cenomanian of Bohemia at Kuchelbad. It is one of the forms which I am tolerably sure I have found on Pennsylvania avenue extended, District of Columbia, and also at Brightseat, Md.

I have gone into these details with regard to the Dakota species found in the Amboy Clays on account of the important bearing that they have upon the correlation of the Potomac flora. Of these 18 species there is probably no doubt whatever, and they would seem to argue for a considerable resemblance between the two floras, but when we remember that the Newer Potomac flora aggregates 347, and that of the Dakota group 460 species, it will be seen that the number of species common to the two is after all not very large. The resemblance is somewhat heightened, however, by the number of other forms provisionally identified in the two formations, which, even if they do not represent identical species, do represent in the main closely related ones. All this is what we ought to expect in comparing the plants that grew on one and the same great continental area, not only within the limits of the Cretaceous system, but during the earlier two-thirds of the period embraced in the Cretaceous epoch. It has been said that the chief difficulty in determining age by means of fossil plants is that these are so long lived. It must be admitted that this objection holds for formations which are closely related geologically, but it only argues for greater caution against generalizing from limited material, as explained by my second "principle."[1] For such restricted periods abundant collections are necessary. This objection applies with still greater force to many animal remains, some of which, such as Lingula,

[1] Principles and Methods of Geologic Correlation by Means of Fossil Plants; American Geologist, Vol. IX, Minneapolis, January, 1892, p. 37. Principes et Méthodes d'Étude de Corrélation Géologique au moyen des Plantes Fossiles; Congrès Géologique International, Compte-rendu de la 5me session (Washington meeting, 1891), Washington, 1893, p. 100.

for example, extend throughout the whole of Paleozoic, Mesozoic, and Cenozoic time, to the present. It also applies to all the animal remains found in the Potomac and Dakota formations, except the vertebrates. The Unios and other shells that are found in these fresh and brackish water deposits are absolutely without geologic value simply on account of the fact that the same species are liable to occur at any horizon.

DISTRIBUTION OF AMERICAN SPECIES.

The other class of Potomac plants that have a distribution outside of that formation, as restricted in this paper, consists, as already remarked, of 35 of the Older Potomac species of Professor Fontaine that have since been identified by him, by Dr. Newberry, or by Sir William Dawson in the Trinity group of Texas, the Kootanie of Great Falls, Mont., and Canada, and in the Shasta group of California. The distribution of these species is shown in the following table:

Potomac species occurring at other localities and horizons.

Species.	Potomac formation.					Other Lower Cretaceous deposits.		
	James River.	Rappahannock.	Mount Vernon.	Aquia Creek.	Lower Albirupean.	Trinity.	Kootanie.	Shasta.
Abietites angustiearpus Font.	.....	+	.....	+	.....	.....	.....	+
Angiopteridium nervosum Font.	.....	+	.....	.....	.....	.....	.....	?
strictinerve Font.	.....	+	.....	.....	.....	.....	.....	?
Aspidium fredericksburgense Font.	+	+	.....	.....	.....	.....	+	.....
heterophyllum Font.	.....	+	.....	.....	.....	.....	.....	+
Asplenioptcris pinnatifida Font.	.....	+	.....	.....	.....	.....	.....	?
Carpolithus virginiensis Font.	+	.....	.....	.....	.....	.....	+	.....
Cephalotaxopsis magnifolia Font.	+	+	.....	.....	.....	.....	.....	?
Cladophlebis constricta Font.	.....	+	?	+	.....	.....	+	.....
distans Font.	+	.....	.....	.....	.....	.....	+	.....
falcata Font.	.....	+	.....	.....	.....	.....	+	.....
inclinata Font.	+	.....	.....	.....	.....	.....	.....	?
parva Font.	.....	+	.....	.....	+	.....	+	.....
Cycadeospermum rotundatum Font.	+	.....	.....	.....	.....	+	?	.....
Dioönites Buchianus angustifolius Font.	+	.....	.....	.....	.....	+	.....	+
Equisetum marylandicum Font.	.....	+	.....	+	.....	.....	?	.....
Laricopsis longifolia Font.	+	.....	.....	.....	.....	+	.....	.....
Leptostrobus longifolius Font.	+	+	.....	+	.....	.....	+	.....
Nageiopsis longifolius Font.	+	+	+	+	.....	.....	.....	+
Osmunda dicksonioides Font.	.....	+	.....	.....	.....	.....	+	?
Pecopteris microdonta Font.	+	+	.....	.....	.....	.....	+	.....
strictinervis Font.	.....	+	.....	?	.....	.....	.....	?
Podozamites acutifolius Font.	+	+	.....	+	.....	?	.....	.....
distantinervis Font.	+	+	.....	?	.....	.....	?	.....
Sagenopteris latifolia Font.	+	.....	.....	.....	.....	.....	.....	?
Sphenolepidium pachyphyllum Font.	+	.....	.....	.....	.....	.....	?	.....
Sternbergianum densifolium Font.	+	+	.....	+	.....	+	.....	.....
virginicum Font.	.....	+	.....	+	.....	.....	+	.....
Sphenopteris latiloba Font.	+	+	?	+	.....	.....	+	.....
Thinnfeldia variabilis Font.	.....	+	.....	+	.....	.....	.....	?
Thyrsopteris brevifolia Font.	+	.....	+	.....	.....	.....	+	.....
brevipennis Font.	+	.....	.....	+	.....	.....	+	.....
insignis Font.	.....	+	.....	.....	.....	.....	?	.....
microloba alata Font.	+	+	.....	.....	.....	.....	?	.....
rarinervis Font.	+	+	+	+	.....	.....	+	?
Zamites tenuinervis Font.	+	+	+	.....	.....	+	.....	.....

Scarcely anything need be said in explanation of this table. Six of the species occur in the Trinity division of the Comanche series of

Texas; 20 of them in the Kootanie group, which includes the Canadian deposits as well as the one at Great Falls, Mont.; and 14 in the Horsetown and Knoxville beds belonging to the Shasta group of California. *Cycadeospermum rotundatum* Font., a James River species, occurs in both the Trinity and the Kootanie, *Dioonites Buchianus angustifolius* Font. in the Trinity and the Shasta, *Osmunda dicksonioides* Font. and *Thyrsopteris rarinervis* Font. in the Kootanie and the Shasta. The last is found in all the Older Potomac beds.

In a considerable number of cases, especially in the Shasta collections, Professor Fontaine has not been willing to express himself positively as to specific identity, and in such cases I have introduced the mark of interrogation. As the floras of these different beds become better developed these doubts will of course disappear, and it is altogether probable that a much larger number of species will be found common to them and to the Potomac flora.

Extra-limital species.—In connection with the subject last discussed the fact may be stated here, to be brought out more fully in a subsequent paper, that from the Lower Cretaceous deposits already mentioned and from several others in America not represented in the last table, 81 species have thus far been described which are not found in the Potomac formation. A few of them are Old World Jurassic and Wealden plants, and some are from the Kome beds of Greenland, but the greater number are new species with a strong Wealden and Jurassic facies. It therefore seems probable that the Lower Cretaceous plant-bearing deposits of Texas, South Dakota, Montana, California, the Queen Charlotte Islands, and Cape Lisburn, Alaska, all belong to that portion of the Cretaceous which is best represented by the Older Potomac at least, and perhaps by the Basal Potomac.

SOME ANALOGIES IN THE LOWER CRETACEOUS OF EUROPE AND AMERICA.

BY

LESTER F. WARD.

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SOME ANALOGIES IN THE LOWER CRETACEOUS OF EUROPE AND AMERICA.

By Lester F. Ward.

INTRODUCTION.

The subdivision of the Cretaceous by the English and Continental geologists differs in the one particular, that while the former make the Upper Cretaceous begin with the Gault the latter make it begin with the Cenomanian. The Lower Cretaceous consists in England of the Wealden beds resting upon the Purbeck, and the Neocomian proper corresponding in the main to the Lower Greensand. The Continental geologists usually divide it primarily into the Neocomian and Urgonian, but M. Lapparent subdivides the Neocomian into the Valanginian and the Hauterivian and reduces the Urgonian to the equivalent of the Atherfield and Punfield beds of England, giving the remainder to the Aptian. His Albian corresponds to the Folkestone beds and the Gault.

The object of this paper is to inquire whether the Lower Cretaceous beds of America present any analogies to those of Europe as thus defined. The best known of these are the Potomac formation of the eastern United States and the Comanche of Texas and adjoining States. Even these have been recognized only a short time, and it was formerly supposed that there was nothing in America corresponding to the lower members of the Cretaceous, the Dakota group being placed at the base of our Cretaceous and the Amboy Clays made equivalent to it, both of which were regarded as equivalent to the Cenomanian. Almost simultaneously with the proof of Lower Cretaceous strata in Virginia and Texas came similar proof of their existence in Alberta and on the Queen Charlotte Islands. The former of these districts is that in which the now somewhat well-known Kootanie beds were discovered. More recently the Kootanie formation has been recognized in the United States, viz, on the upper Missouri River in the vicinity of Great Falls, Mont. It is also probable that the lower portion of the Cretaceous of the Black Hills which has yielded gigantic cycadean trunks, much silicified wood, and a large number of fossil plants of Lower Cretaceous types, belongs to the Kootanie forma-

tion.[1] Lower Cretaceous strata are also now known to occur on the Pacific Coast, the Shasta formation belonging to that horizon. The Tuscaloosa formation of Alabama and Mississippi was long supposed to lie very low in the Cretaceous, and was definitely correlated by Dr. C. A. White[2] with the Potomac formation in Virginia. But large collections of fossil plants from the Tuscaloosa beds prove that they can not be much lower than the Amboy Clays or Raritan formation of New Jersey.

With the exception of the Comanche series and the Pacific Coast deposits above referred to, the paleontological evidence of the age of all these beds is almost exclusively that of their plant remains, and the few shells that occur in them indicate either a fresh-water or brackish-water condition and seem to prove that they are for the most part estuarine or delta deposits. The case is somewhat the same in Europe, the entire Wealden and much of the Neocomian proper being of fresh-water origin, or at least having been deposited in somewhat shallow water. The American beds, except in Texas, consist chiefly of sands and clays, often hardening into sandstones and clay-shales, and are devoid, for the most part, of calcareous matter. In Europe, on the contrary, nearly all the deposits are partially calcareous and there are some true limestones.

Having devoted four years to a somewhat careful study of the Lower Cretaceous of America, and especially of the Potomac formation, but including field studies in the Tuscaloosa formation of Alabama, in the Comanche series of Texas and Arkansas, and in the Kootanie of Montana and the Black Hills, and being somewhat familiar with the rich fossil flora of this general horizon as developed in America, chiefly by Professor Fontaine, Dr. J. S. Newberry, Dr. Arthur Hollick, and Sir William Dawson, I felt more and more strongly the importance of comparing the conditions prevailing in this country with those of England and the Continent. This feeling, taken in connection with the practical necessity of seeing the collections from this horizon in the several museums of Europe, determined me to spend a portion of the past season there in the investigation of this question. What I accomplished was of course very slight, as I was only absent from this country two months, fully half of which was spent in transit and in attending scientific meetings. In fact, the only field work undertaken consisted of three excursions to critical localities, the first to the Isle of Portland, the second to the Isle of Wight, and the third to an important locality near Bologna, in Italy, in the valley of the Reno, where the "Scaly Clays" (*argille scagliose*) are best exposed. In the limited time at my disposal I decided, I think rightly, that the careful examination of a few such classical localities, the most typical of the entire Lower Cretaceous period, would be more profitable than a rapid survey of a much wider

[1] See Science, New Series, Vol. I, New York, February 1, 1895, pp. 137–138.
[2] Bull. U. S. Geol. Surv. No. 82: Correlation Papers—Cretaceous, p. 217.

field without opportunity of closely examining any part of it. The remainder of the time at my disposal was spent in the museums of Europe in an inspection of the important types of fossil plants from this general horizon, especially in the careful study of the cycadean trunks in the British Museum, the Paris Museum, and at the University of Bologna, together with the microscopic preparations that have been made of this class of material. To this I may add here the bare mention of a visit to the south of France to inspect the Lower Cretaceous material lately collected in Portugal and then in the hands of the late Marquis Saporta, of which more will be said later. I shall confine myself chiefly to the three countries mentioned, viz, England, Italy, and Portugal, and speak of them in that order.

COMPARISON OF THE POTOMAC FORMATION OF AMERICA WITH THE WEALDEN OF ENGLAND.

In the last annual report of the United States Geological Survey, pp. 307–341, I have set forth somewhat in detail the stratigraphical relations of the Potomac formation. These need not be repeated here at length, and I shall confine myself to those more general considerations which furnish points of comparison between America and Europe. It is not, of course, to be expected that in countries so remote from each other the more detailed conditions will possess sufficient similarity to admit of comparison, and all that can be claimed, and that which properly constitutes the thesis of this paper, is that there do exist certain very general resemblances between the Lower Cretaceous strata of America and those of Europe. In one sense it is, of course, true that all sedimentary deposits the world over and throughout all geologic time have certain broad characters in common; but it is not with these that I propose to deal, but with characters which, though general in one sense, may be looked upon as specific in another; characters not common to all sedimentation; characters scarcely recognizable in Paleozoic deposits, and also differing widely from what we find in the Tertiary or Pleistocene age, and therefore to some extent confined to the Mesozoic—confined even to the Cretaceous, and in a great degree to the Lower Cretaceous. For example, it would seem that, at the beginning of the period at which the Cretaceous system is by common consent fixed, conditions existed on both sides of the Atlantic favorable to the production of large estuaries or lakes, in which were deposited heavy beds of sands and clays differing radically from anything which had preceded them, as well as from what followed them. In most cases the lower portions of these estuarine, fluviatile, or lacustrine deposits consist mainly of sands, while the upper portion consists mainly of clays; but throughout the sands there occur interstratified seams of clay, and throughout the clays layers of sand, while in general all sands are somewhat argillaceous and all clays somewhat arenaceous. This, as I have shown, is certainly the case in the Potomac formation

of the Atlantic border; it is also true of that extension of the Potomac known as the Tuscaloosa formation of the Gulf border. The trans-Mississippi extension of the same system known as the Comanche series differs in the important particular of having heavy beds of limestone; but so far as I am aware the Kootanie formation is nowhere a marine deposit.

We will consider first the Potomac formation and examine a few of the descriptions which have been made of its characteristic materials by those who are most competent to speak in this connection. Prof. W. B. Rogers, when State geologist of Virginia, thus described the sand and sandstones in the vicinity of Fredericksburg:

> In composition they are merely a mixture of quartz and feldspar, in rather loose cohesion—the feldspar often decaying rapidly on exposure. In some varieties, the rounded pebbles are not larger than birdshot; in others, they attain a diameter of many inches. In certain localities, the sandstone has a fine, close texture, suiting it for various useful purposes, and is employed to a considerable extent in building. The quarries in the neighborhood of Fredericksburg and Aquia Creek present beds of great thickness of a homogeneous rock of this description, of which extensive use has been made in some of the public edifices in Washington, Richmond, and elsewhere. In the superior portion of these beds, lignites, silicified wood, and vegetable impressions are, frequently to be seen.[1]

Prof. William M. Fontaine, describing the coarse sandstones of the James River system, says:

> The greater portion and the finer matter of the beds is a sort of incoherent grit, composed of grains of quartz, particles of feldspar in all stages of decomposition, and scales of mica, all mingled together without sorting and devoid of lamination, forming a mass without bedding, but penetrated by numerous and intricate false-bedding planes.[2]

Mr. W J McGee, in the original paper in which he named the Potomac formation, thus described its general characteristics:

> It is made up of fine, homogeneous, plastic clay, sand of various degrees of fineness, gravel, sometimes coarse and again fine, and occasional bowlder beds, which materials are sometimes indiscriminately intermingled, but generally occur as distinct strata or beds somewhat irregular in altitude, but exhibiting a general inclination of a few degrees to the eastward.[3]

In a notice of the above-quoted work, about the same date, Mr. McGee thus somewhat slightly expands his description of the Potomac formation:

> In structure and composition it is bipartite, the upper portion consisting of highly colored banded and mottled clays, with intercalations of sand and quartzose gravel, and the lower of sand and gravel with intercalations of clay. In both divisions stratification is inconstant and often absent, and the materials are sometimes indiscriminately intermingled. The formation is practically destitute of fossils in the District [of Columbia], but yields abundant plant remains in Maryland and Virginia. It appears to consist of inosculating deltas of the Potomac and other Atlantic

[1] Geology of the Virginias, p. 70.

[2] Amer. Journ. Sci., 3d ser., Vol. XVII, 1879, p. 230.

[3] Report of the Health Officer of the District of Columbia for the year ending June 30, 1885, Washington, 1886, p. 20.

Coast rivers and the littoral deposits into which they merge, laid down along a bay-indented coast upon a highly inclined and irregular sea-bottom produced by combined depression and seaward tilting of a deeply corroded land surface in late Jurassic or early Cretaceous time.[1]

Describing the Fredericksburg sand in a later paper Mr. McGee says:

It consists predominantly of locally lithified arkose with abundant pebbles either irregularly disseminated or arranged in bands and oeds, and numerous bowlders of gneiss and vein-quartz (quartzite being altogether absent) up to two feet or more in diameter, together with heterogeneous sand containing a considerable element of finely divided diffused clay; while lenticular beds of clay are frequently intercalated in both arkose and sand, and in some exposures constitute the major part of the mass.[2]

His latest utterance on this subject, so far as I am aware, is as follows:

The basal formation of the coastal plain series (the Potomac) outcrops along the fall line from the Delaware to the James as a heterogeneous mass of sand, clay, arkose, and quartzitic or quartzic gravel. The arkose unquestionably represents the neighboring Piedmont crystallines; the quartzite is evidently derived from the extensive Paleozoic beds forming the Blue Ridge; the quartz represents the veins by which the Piedmont crystallines are frequently intersected.[3]

I have myself shown[4] that the Potomac formation consists in its most general aspects, and considered from base to summit throughout its entire extent, of the following subdivisions, which, though not always present at all points, occur in the order named and possess substantially the characteristics assigned to them:

I. *The James River series.*—Beds of dark, sometimes greenish, clay, weathering red or purple. When dark and carbonaceous, usually plant-bearing, often appearing as lenses in heavy beds of coarse sand.

II. *The Rappahannock series.*—Coarse feldspathic sand and sandstone, usually separated by thin layers of more or less argillaceous shale, often plant-bearing.

III. *The Mount Vernon series.*—A local bed of chocolate-colored clay, superposed upon the last-named member, yielding a peculiar flora.

IV. *The Aquia Creek series.*—Alternating sands and clays, the latter laminated and usually plant-bearing, the former much finer and softer than the feldspathic sand of No. II, but consisting largely of that member redeposited.

V. *The Iron Ore series.*—Highly colored, mostly red, purple, or mottled plastic clay, usually massive and nonfossiliferous.

VI. *The Albirupean series.*—Alternating sands and clays, more or less regularly interstratified, the sands much finer than in any of the lower members, the clays often carbonaceous and plant-bearing, sometimes of a light-drab color. At the top of the Albirupean series occurs what I call the Island series, confined to Staten Island, Long Island, Marthas

[1] Amer. Journ. Sci., 3d ser., Vol. XXXI, June, 1886, p. 474.

[2] Amer. Journ. Sci., 3d ser., Vol. XXXV, February, 1888, p. 128.

[3] Geology of Washington and Vicinity, by W J McGee, etc., Compte-rendu du Congrès Géologique International à Washington en 1891, p. 237.

[4] The Potomac Formation, Fifteenth Annual Report, U. S. Geol. Surv., 1893–94, Washington, 1895, pp. 307–397.

Vineyard, etc., consisting of reddish clays, in which ferruginous nodules occur holding plant remains. These clays sometimes take the form of red ferruginous shales, usually micaceous, scattered slabs of which found on the beaches of Long Island and Staten Island have yielded fossil plants.

In making the proposed comparisons between the Lower Cretaceous of America and Europe I shall, for the sake of compactness, limit them chiefly to the Potomac formation of the United States and the Wealden of England. Too little is known of the Lower Cretaceous of other parts of America to make it profitable to discuss it, while the deposits classed as Wealden in other parts of Europe are not always satisfactorily identified with the Wealden of England, and an attempt to describe them would add little to what can be gained without this. It is evident that in a comparison of this kind the term Wealden must be given a somewhat wider meaning than that which is now commonly applied to it by the English geologists. That is to say, the scope of the formation will depend upon the point of view from which it is considered. From its fossils alone it is restricted to those deposits which lie between the Purbeck below and the Atherfield and Punfield strata above. But when the subject is considered from the point of view of the origin of the beds and the manner in which they were laid down it becomes impossible thus to restrict it, and we are obliged to embrace under the term Wealden the whole of the Purbeck beds below, and those transition beds above, which do not properly belong to the true marine Neocomian or Lower Greensand. We thus have a clear and well-defined geological unit, although the fossils of the Purbeck indicate that these beds belong to the Jurassic, while those of the transition beds mentioned are very different from those of the Wealden. This affords another good illustration of the importance of the principle of "dual nomenclature" in geology, according to whether we are considering phenomena from the standpoint of age or time, or from the standpoint of geological integrity.

In reviewing the history of the Wealden it will be convenient to look at it from two points of view, viz, first, as to its mode of formation or deposition, including the question of whether the beds are of estuarine, fluviatile, or lacustrine origin; and secondly, as to its materials; under both of which heads I shall give descriptions that occur in works of the prominent geologists of England.

The earlier geologists, who were apt to be influenced by the broader considerations, generally inclined to class the Purbeck with the Wealden. This was notably the case with Dr. Mantell in his numerous works dating back to his Geology of Sussex, 1822; also with Dr. William Fitton in his extended paper on the Strata below the Chalk.[1] Mr. C. J. A. Meyer as late as 1872 also took substantially the same position.[2] Indeed, as

[1] Trans. Geol. Soc. London, 2d ser., Vol. IV, 1835, pp. 103–388* (see p. 159).
[2] Quart. Journ. Geol. Soc. London, Vol. XXVIII, 1872, p. 243.

we shall see, all geologists when discussing the origin of the Wealden beds have been driven to this assumption.[1]

ORIGIN AND MODE OF DEPOSITION OF THE WEALDEN.

For a long period geologists were so intent on determining the age of formations by means of their contained fossils that very little attention was paid to beds in which such fossils were absent. And during about the same period animal fossils were considered to be almost the only ones of any value for this purpose. It is natural, therefore, that geological investigation should have been in the main restricted to marine deposits, and certain beds of great thickness which were not laid down in deep water were largely ignored. Such was the case with the Wealden of England, and but for the circumstance that this formation actually did yield a considerable number of animal remains it would have doubtless been still worse neglected. Dr. Mantell was almost the only one to lay stress on the vegetable remains and to insist that they had a geological importance. The history of American geology has even more strongly emphasized this tendency on the part of geologists to leave out of view the fresh-water deposits of the country, and it is only within quite recent times, and especially since paleobotanists have directed their attention to them, that they have begun to receive adequate consideration. Professor Huxley had observed this tendency, and in his paper on Hyperodapedon read before the Geological Society of London on January 13, 1869, he was led to make the following significant remark:

> At present our knowledge of the terrestrial faunæ of past epochs is so slight that no practical difficulty arises from using, as we do, sea-reckoning for land time; but I think it highly probable that sooner or later the inhabitants of the land will be found to have a history of their own—mixed up with that of the sea, indeed, but independent of it, in some such relation as the histories of England and that of France.[2]

Mr. Godwin-Austen, in the address already referred to, realizes this fact, and expresses himself in the following language:

> Great periods, during which wide marine conditions prevailed, alternated with others of wide terrestrial surfaces. The marine periods, as we measure them by the products of the agents which seas and oceans call into action, must have been of vast duration. In like manner we may feel assured that the great freshwater formations are not, as some geologists have supposed them, mere subordinate parts of the great marine groups, as our "Wealden" of the "Cretaceous," but rather true intermediate groups, of equal geological value with them in the estimate of past time.[3]

We may next consider the various expressions of geologists relative to the origin of the Wealden. Dr. Fitton said that "The mode in which the Wealden is disposed, in the southeast of England, accords with the

[1] See Topley, Geology of the Weald, 1875, p. 321; Godwin-Austen, Brit. Ass. Rept., 42d Meeting, Brighton, 1872, Pt. II, p. 93; Phillips's Manual of Geology, Pt. II, by Robert Etheridge, London, 1885, p. 505.

[2] Quart. Journ. Geol. Soc., London, Vol. XXV, 1869, p. 150.

[3] Brit. Assn. Rept., 42d Meeting, Brighton, 1872, Pt. II, p. 91.

hypothesis of its having originated in a lake of fresh water, or in the estuary of a large river."[1] Dr. Mantell regarded the Wealden as "the delta of a river, composed of the spoils of a vast continent, of which no other vestiges remain."[2] Messrs. Robertson, Murchison, Wood, and Meyer have further ably discussed this question, some maintaining that the Wealden is a purely lacustrine formation, but most of them admitting a greater or less connection of the Wealden waters with those of the sea. The last author named stoutly defends what he calls the fluvio-lacustrine character of the strata, and remarks:

> To the fluvio-lacustrine origin of the Wealden strata which I propose to advocate, many objections may of course be raised; but these I shall not anticipate, the objections to their purely fluviatile or estuarine origin appearing to me to be of greater weight. The exceedingly quiet deposition of much of the sedimentary strata, the almost total absence of shingle, the prevalence, both numerically and specifically, of such species of mollusca as delight most in quiet waters, the comparative absence throughout the greater portion of the series of broken shells such as always abound in tidal rivers, and, I believe I may say also, the total absence of any trace of drift-wood perforated by mollusca in either the Purbeck or Wealden strata; all seem to me to point to the same conclusion—namely, to the accumulation of such strata beneath the waters of a wide but shallow lake, whose superfluous waters during the middle Wealden era escaped, indeed, to the sea, but only by some narrow outlet, and whose area was perhaps occasionally, though rarely, invaded by the ocean.[3]

Judging from these statements and many others that might be adduced, it seems sufficiently clear that the Wealden of England, in the broad sense in which I use the term, can not widely differ in its mode of deposition from the Potomac formation of the United States, which is usually referred to as of estuarine or fluviatile origin, and which is in fact undoubtedly a combination of these two, the waters of the Potomac sea having consisted chiefly of extended estuaries similar to the Chesapeake and Delaware bays, which may be regarded as simply the widening of the principal river systems (Susquehanna, Delaware, etc.) flowing into them. The evidence in the case of the Potomac formation points much more clearly to this condition than it does either to a purely lacustrine origin or to a delta formation; although there may have been at places bodies of waters which were not thus entirely open to the sea but which possessed a somewhat constricted outlet, while at other points the deposits may have been near the head of these great estuaries, where the conditions partake more nearly of the character of a delta.

The remarkable fact is that the two great deposits on the east and the west sides of the Atlantic were, so far as can be judged from all the evidence at hand, practically synchronous. It is true that in the Potomac formation we have thus far discovered no beds whose organic remains prove them to have been actually Jurassic in age correspond-

[1] Trans. Geol. Soc., London, 2d ser., Vol. IV, 1835, p. 324.
[2] Geology of the Isle of Wight, London, 1847, p. 65.
[3] Quart. Journ. Geol. Soc., London, Vol. XXVIII, 1872, p. 243.

ing to the Purbeck; but it is also probably true that we have never as yet found any exposures of the absolute base of the formation, and there is much evidence to show that the lowest beds known are still further underlain by thick deposits of unknown character which could only be discovered by borings farther out on the coastal plain than any that have yet been made. This is because the deposits were formed during a period of loading and consequent subsidence, as a result of which the landward margin has the form of a wedge, those deposits nearest the margin being of a later date than those formed farther out in the Potomac sea.

LITHOLOGICAL CHARACTER OF THE WEALDEN.

Having thus seen that the Potomac and the Wealden are not only practically of the same age but also of the same epeirogenic origin, we will next consider their stratigraphical and lithological character. The Purbeck beds, which constitute the lowest deposits of the greater Wealden, are best exposed on the Isle of Portland and the Isle of Purbeck. They have been so frequently described and are so well known to geologists generally that it scarcely seems necessary to dwell upon them, and it need only be said that they consist of fresh-water limestones, clays, shales, and sandstones, and include two very remarkable swamp deposits known as the "dirt beds," which have furnished the well-known trunks of cycads, and in which are inserted the roots of great coniferous trees, whose trunks rise above the overlying shales and have been an object of interest for ages. The apparent distinction between the Purbeck and any known deposit of the Potomac by the occurrence in the former of calcareous deposits is in a great measure removed upon the hypothesis that the lime occurring in these deposits is not the result of organic life at the period, but is merely derived by erosion from the underlying limestones of the Portland.[1]

The Wealden proper consists, as already remarked, of alternating beds of sands and clays, of which the sands predominate below and the clays above. The lowest beds were called the Hastings Sands by Dr. Fitton in 1824, as a substitute for the less correct names, "ferruginous sands" and "iron sands," which had previously been applied to them. These are now further subdivided and are found to contain clay seams of considerable thickness, notably the Wadhurst Clay, interstratified between the Ashdown Sand and the Tunbridge Wells Sand. Dr. Fitton says: "The Hastings sands in the Isle of Wight may be described as consisting of an alternating series of beds of sand,—more or less abundant in ferruginous matter, and containing courses, generally in concretional form, of calcareous grit,—with beds of clay, much mixed with sand, of a greenish or reddish hue, or of a mottled and variegated appearance."[2] Mantell's description of the Tilgate Grit and Hastings

[1] See Godwin-Austen in Brit. Ass. Rept., 42d Meeting, Brighton, Pt. II, 1872, p. 93.
[2] Annals of Philosophy, Vol. VIII, New Ser., London, 1824, p. 377.

Sands is as follows: "Fawn-colored sand and sandstone; with beds of calcareous grit; blue clay, marl, and lignite."[1]

It is remarkable that this basal sand of the Wealden, like that of the Potomac, is often indurated into a sand rock, which in both cases sometimes becomes a workable freestone and is used for building purposes; although in neither case is this building stone of a very excellent quality.

The so-called Weald Clay, which succeeds the lower and more sandy deposits, bears perhaps a still greater resemblance to the red and mottled clays of the upper portions of the Potomac than do the Wealden sands to the Potomac sands. It was this that particularly struck me on my visit to the Isle of Wight. Before examining the Wealden deposits I had seen the celebrated cliff at Alum Bay, which has been so often compared by American geologists with the cliff at Gay Head, Marthas Vineyard. The resemblance is certainly striking at first glance, but a careful examination quickly indicates radical differences. On the contrary, the more one studies the red clay of the Wealden on the southwest side of the island the greater the resemblance becomes, not especially with the beds of Gay Head, which are so considerably tilted as to render the comparison less exact, but with the vast masses of this highly-colored clay that occur in the Potomac formation in Delaware and Maryland. The principal distinction is in the greater degree of lamination in the Wealden strata; but almost complete identity presents itself in cases where these strata have been broken down and lie in the form of talus at the base of the cliff. Where this talus is of long standing an alteration has taken place which renders the mingled materials far more homogeneous, gives the clays a much more plastic character, and distributes the color in streaks and blotches precisely similar to those of the Potomac mottled clays. This fact strongly suggested to my mind that the greater part of our Potomac clays of this character may have undergone a secondary deposition, and there are many other facts that tend to confirm this view. The descriptions of the mottled clays of the Wealden that we find in the books are sufficient of themselves to suggest to the student of the Potomac formation a close relationship. It is often referred to as "variegated clay," but where more specifically described the numerous hues of red, pink, purple, etc., are always mentioned.[2]

It is not to be expected that the special subdivisions of the Wealden and Potomac could be made to correspond any more nearly than is indicated by the general statement already made that the sands predominate below and the clays above. Clay seams are found quite low down in the lowest members of the Wealden, but nothing would be

[1] Geology of the Isle of Wight, 1847, p. 63.

[2] See Fitton, Trans. Geol. Soc., London, 2d. ser., Vol. IV, pp. 185, 199, 200; Mantell in Quart. Journ. Geol. Soc., London, Vol. II, 1846, p. 92; Frederick Drew, op. cit., Vol. XVII, 1861, p. 273; Meyer, op. cit., Vol. XXVIII, p. 247; Topley, Geol. of the Weald, 1875, pl. v, facing p. 4, p. 96; Bristow, Geology of the Isle of Wight, 2d ed., 1889, pp. 3, 5, 6, 15, 16.

U.S.GEOLOGICAL SURVEY

GEOLOGIC MAP OF S

ITH EAST OF ENGLAND

A. Hoen & Co. Lith. Baltimore.

gained by attempting to compare these with the heavy beds of greenish and purplish clays that lie at the present known base of the Potomac.

If we assume that the Purbeck beds correspond to buried portions of the Potomac which have not yet been brought to light, the corresponding parts of the Wealden, looked at from below upward, are: (1) the Ashdown Sands, 400 or 500 feet; (2) the Wadhurst Clay, 120 to 180 feet; (3) the Tunbridge Wells Sand, 140 to 380 feet; and (4) the Weald Clay, 1,000 feet.[1]

My own estimate of the thickness of the Potomac formation, as made in the last Annual Report, footed up 1,175 feet,[2] of which over 500 feet are assigned to the lower or more sandy portions; but in the Potomac formation there is evidence of great erosion during the period, and if all could be measured there is no doubt that the thickness would be increased to 1,500 or 2,000 feet. The measurements of the Wealden have been increasing from year to year, that of Etheridge in 1885 bringing it up to 1,800 feet; the more elastic estimate of Geikie, just given, would make it range between 1,660 and 2,060 feet. In general, then, it may be safely said that so far as is at present known the Potomac formation of the eastern United States and the Wealden formation of England are of practically the same thickness.

So far as the Atherfield and Punfield beds are concerned, they may be compared with certain partially marine deposits, immediately succeeding the highest Potomac beds. There is much evidence that the process of deposition was not abruptly changed in passing from the one to the other. There are certain localities, as on the eastern shore of the Chesapeake and on the south side of Raritan Bay, where this gradual transition is very noticeable, the Clay Marl of the New Jersey geologists (Matawan formation of Clark) being, at least at its base, only slightly glauconitic, and containing abundant lignite and other vegetable remains and a very meager fauna. It must not, however, be inferred that these American transition beds are of the same age as the Atherfield and Punfield beds of England. They correspond more closely with the Upper Greensand, which is regarded as of Cenomanian age, or Upper Cretaceous, and there seems to be nothing in England at all analogous to our Newer Potomac, which is about the age of the Gault.

In searching for a map of the Wealden of England I have not been able to find one among the more recent works that seemed to serve the present purpose as well as that of Dr. Fitton, published in connection with the paper I have so often referred to on the "Strata below the Chalk."[3] The essential portion of this map is given in Pl. XCVII.

[1] Archibald Geikie, Text-Book of Geol., 1882, p. 817.
[2] Fifteenth Ann. Rept. U. S. Geol. Surv., 1893–94, pp. 339, 340, fig. 3.
[3] Trans. Geol. Soc., London, 2d ser., Vol. IV, 1835, pl. ix.

The Isle of Wight has entered so largely into the foregoing discussions that I have thought it appropriate to exhibit a small map of it. Here again I have found the more modern maps too detailed for my purpose and have used the excellent one that accompanies Dr. Mantell's Geology of the Isle of Wight (see Pl. XCVIII).

I have also reproduced from the same work his ideal section of the dynamic conditions attending the deposition of the Wealden beds (see Fig. 67).

COMPARISON OF THE FOSSIL FLORAS.

The Lower Cretaceous of England, while much richer in animal remains, is far less rich in vegetable remains than that of America. In fact, so few of the former have been found in this country, and these few have so little significance for geology, that any comparison that might be undertaken would be of slight value. Still the few vertebrate remains found in the Potomac formation of Maryland are of Saurian types not widely different from those of the English Wealden. It will, therefore, be necessary to limit the comparison to the floras of these respective areas. In America nearly a thousand different forms of vegetable life have been brought to light, many of which remain to be

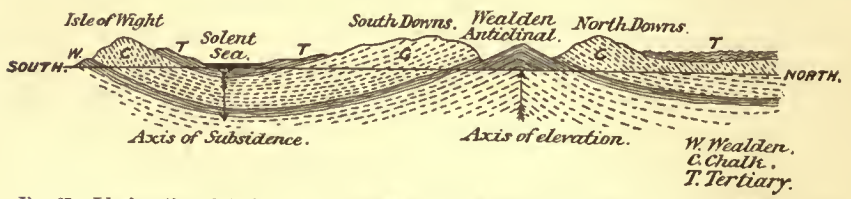


FIG. 67.—Ideal section of the Wealden of England, from Mantell's Geology of the Isle of Wight, 1847.

described, but over eight hundred species are already recorded in the different memoirs thus far published and in preparation, more than seven hundred of which are embraced in the Potomac flora. These are from a considerable number of horizons extending from the Basal beds of the James River to the uppermost deposits of the Raritan formation, which must lie very close to the line that should mark off the Lower from the Upper Cretaceous. In these upper beds we have, as has been shown in the paper already referred to,[1] a great dicotyledonous flora which has no representative in the English Lower Cretaceous. The few forms that have been collected from the Upper Greensand and Gault in England are nearly all coniferous, and thus far not a single dicotyledonous form has been reported from that country below the Eocene. Our comparisons will therefore be practically with the Older and Middle Potomac, the Trinity of Texas, and the Kootanie of the Northwest. As a basis for the discussion I introduce here a table of the Wealden flora, as complete as I am able to make it at this date, showing its distribution not only in America, but in other parts of the

[1] Fifteenth Ann. Rept. U. S. Geol. Surv., 1893–94, pp. 307–397.

world. Eighty distinct forms are embraced in this list. They include 2 algæ, 2 fucoids, 1 hepatic (*Marchantites Zeilleri* Seward), 1 Chara (*C. Knowltoni* Seward), 3 equiseta, 23 ferns, 22 cycads, 24 conifers, 1 monocotyledonous plant (*Dracæna Benstedi* Koenig), and some undetermined seeds.

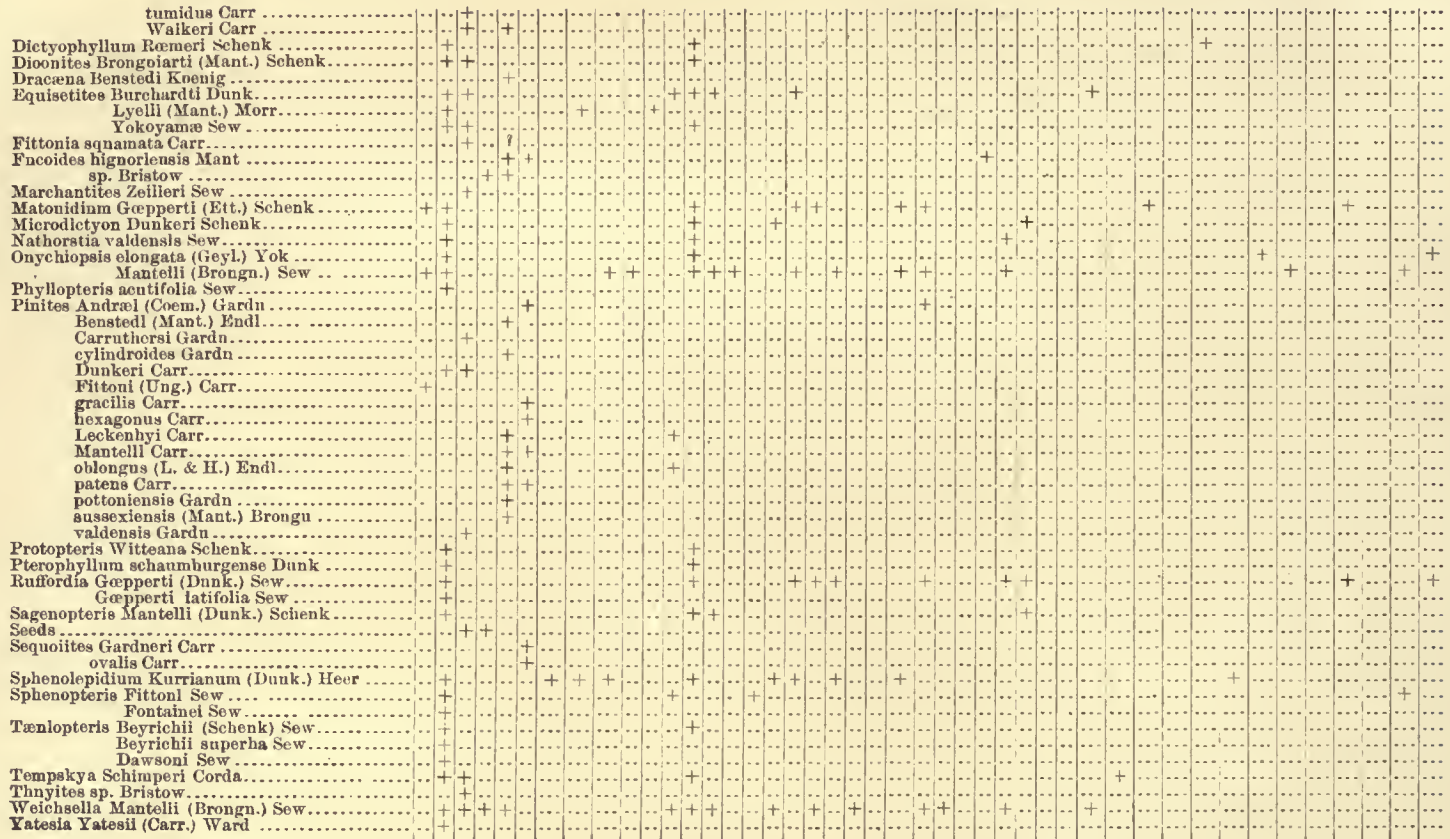
This list will probably be considerably extended when Mr. Seward shall have completed his studies of the Wealden flora, of which he has thus far published only the cryptogamic species.[1] He will doubtless also find reason for making extensive changes in the names here introduced, some of which are very old and badly in need of revision. Mr. Seward has confined himself exclusively to the Wealden in its restricted sense, and the bulk of the material at his disposal has been recently collected by Mr. P. Rufford from beds in the vicinity of Hastings. He has, however, worked over all the old material in the British Museum, and done the best that was possible with the older collections of Mantell, Webster, Fitton, and Buckland, and has embodied the later researches of Carruthers and Gardner. Unfortunately, however, many of the old types are lost, or at least their whereabouts are not now known, so that when not figured their identification is difficult.

I have in this table, as in the foregoing geological discussion, taken the broader view of the Wealden, and included the Purbeck beds below and the Atherfield beds above, and in order better to compare the flora with that of the United States I have included the Lower Greensand and the Gault. These constitute the first six columns of the table, in immediate juxtaposition with which I have placed the Lower Cretaceous of the United States, arranging the Potomac beds in their ascending order (James River, Rappahannock, and Aquia Creek), followed by the Trinity and the Kootanie, in all of which English Lower Cretaceous plants occur. The Kootanie of Canada is doubtless the same in age as that of Montana, and I have not therefore thought best to give it a separate column. In order to bring the most nearly related beds as close together as possible I have made the general distribution begin with the Wealden, and find it to include France, Germany, Austria, Moravia, and New Zealand. Then follow those deposits which are classed as Neocomian in Westphalia, Portugal, and Russia, the Urgonian of Portugal, Austrian Silesia (Wernsdorf beds), and Greenland (Kome beds), the Aptian and Albian (Gault) of Portugal, and the Gault of England (Folkestone), Belgium (Hainaut), and Westphalia, terminating the comparison with the equivalent Lower Cretaceous deposits. The distribution, however, extends to the higher Cenomanian deposits of England (Upper Greensand), Saxony (Niederschoena), Bohemia, and Greenland (Atane), and to the Senonian of Germany (Westphalia, Blankenburg).

[1] Catalogue of the Mesozoic Plants in the Department of Geology British Museum (Natural History). The Wealden Flora, Part I. Thallophyta-Pteridophyta, by A. C. Seward, London, 1894.

Table of distribution of the plants of the Lower Cretaceous of England (Purbeck to Gault, inclusive).

Species.	Lower Cretaceous of England.							Lower Cretaceous of the United States.				Wealden.							Neocomian.				Urgonian.			Aptian of Portugal	Gault or Albian.			Cenomanian.				Senonian of Germany.	Buntersandstein of Alsatia.	Rhetic of Bavaria.	Lias.			Lower Jurassic.			Oolite.		Upper Jurassic.	
	Purbeck.	Hastings Sands.	Weald Clays.	Atherfield beds.	Lower Greensand.	Gault.	Potomac. James River.	Rappahannock.	Aquia Creek.	Trinity.	Kootanie.	France.	Germany.	Austria.	Moravia.	New Zealand.	Westphalia.	Portugal.	Russia.	Portugal.	Austrian Silesia.	Greenland.	Belgium.	Westphalia.	Portugal.	England.	Saxony.	Bohemia.	Portugal.	Greenland.								England.	Bornholm.	Hungary.	China.	India.	Australia.	Yorkshire.	Spitzbergen.	Portugal.	Japan.
Acrostichopteris Ruffordi Sew		+																																											
Algites catenelloides Sew		+	+																																										
valdensis Sew			+																																										
Araucaria pippingfordensis (Ung.) Schimp				+									+																																
Araucarioxylon antediluvianum Ward					?																																							
Wallacei Kn					+																																							
Webbii Kn					+																																							
Bucklandia anomala (Stokes & Webb) Presl					?																																							
Mantelli Carr					+																																							
Chara Knowltoni Sew		+	+																																									
Cladophlebis Albertsii (Dunk.) Brongn		+																																										
Browniana (Dunk.) Sew		+							?																																			
Dunkeri (Schimp.) Sew		+							+																																			
longipennis Sew		+							+																																			
Coniferous wood		+				+																				+																		
Cycadeoidea Carruthersi Ward		+				+																																						
Gibsoni (Carr.) Ward						+																																						
inclusa (Carr.) Schimp						+																																						
maxima (Carr.) Solms						+																																						
megalophylla Buckl																																												
microphylla Buckl																																												
Morierei (Ren.) Ward																																												
portlandica (Carr.) Solms																																												
Saxbyana (R. Br.) Morr																																												
Cycadeostrobus Brunoois Carr			+																																									
crassus Carr			+																																									
elegans Carr			+																																									
ovatus Carr			+																																									
truncatus Carr			+																																									


tumidus Carr
Walkeri Carr
Dictyophyllum Rœmeri Schenk
Dioonites Brongniarti (Mant.) Schenk
Dracæna Benstedi Kœnig
Equisetites Burchardti Dunk
Lyelli (Mant.) Morr
Yokoyamæ Sew
Fittonia squamata Carr
Fucoides hignorlensis Mant
sp. Bristow
Marchantites Zeillieri Sew
Matonidium Gœpperti (Ett.) Schenk
Microdictyon Dunkeri Schenk
Nathorstia valdensis Sew
Onychiopsis elongata (Geyl.) Yok
Mantelli (Brongn.) Sew
Phyllopteris acutifolia Sew
Pinites Andræi (Coem.) Gardn
Benstedi (Mant.) Endl
Carruthersi Gardn
cylindroides Gardn
Dunkeri Carr
Fittoni (Ung.) Carr
gracilis Carr
hexagonus Carr
Leckenhyi Carr
Mantelli Carr
oblongus (L. & H.) Endl
patens Carr
pottoniensis Gardn
sussexiensis (Mant.) Brongn
valdensis Gardn
Protopteris Witteana Schenk
Pterophyllum schaumburgense Dunk
Ruffordia Gœpperti (Dunk.) Sew
Gœpperti latifolia Sew
Sagenopteris Mantelli (Dunk.) Schenk
Seeds
Sequoiites Gardneri Carr
ovalis Carr
Sphenolepidium Kurrianum (Dunk.) Heer
Sphenopteris Fittoni Sew
Fontainei Sew
Tæniopteris Beyrichii (Schenk) Sew
Beyrichii superba Sew
Dawsoni Sew
Tempskya Schimperi Corda
Thuyites sp. Bristow
Weichsella Mantelli (Brongn.) Sew
Yatesia Yatesii (Carr.) Ward

The Triassic and Jurassic distribution embraces the Buntersandstein of the Vosges, the Rhetic of Bavaria, the Lias of England, Bornholm, and Hungary, the Jurassic beds of China, India, and Australia, whose proper position it is difficult to assign, the Oolite of Yorkshire and of Spitzbergen, the Upper Jurassic beds of Portugal, which are perhaps the equivalent of the Kimmeridge clays, and those Mesozoic deposits of Japan from which Yokoyama and Nathorst have obtained so many fossil plants, and which may prove to belong to the Neocomian, but are probably extreme Upper Jurassic.

A glance at the table will show which plants possess a wide geographical distribution, and also which have an extended geological range. It will also make clear the relationships of the Wealden to the American floras. Mr. Seward has given this question special attention, and has shown that a number of Potomac ferns are common to the Wealden of England; such are especially the *Cladophlebis Browniana* (Dunk.) Seward, and *C. Dunkeri* (Schimp.) Seward, and the *Onychiopsis elongata* (Geyl.) Yok. (now made to include part of *Sphenopteris Gœpperti* Dunk.), *Dicksonia elongata* Yok., and *Thyrsopteris elongata* Geyl. He also maintains that the widely diffused *Thyrsopteris rarinervis* of Foutaine is identical with this species. In marking the distribution of this plant I have not accepted this decision as final. When he comes to discuss the coniferous species he will probably cause the connection between the Wealden and the Potomac to appear still more close by tracing in many cases the relationships of the English forms to those of America.

CYCADEAN TRUNKS.

Special attention should be called to the cycadean vegetation. Since the great cycad forest of the Black Hills of South Dakota was discovered,[1] and since the extraordinary development of cycadean vegetation in Maryland has been made known by Mr. Arthur Bibbins,[2] the interest in this group of plants has been greatly increased. As nearly all of this new American material had come into my hands for study, and as none of the Old World specimens, long ago described, were accessible for comparison, I felt the necessity of laying special stress upon this aspect of my work in Europe. Accordingly, I not only examined all the material in the British Museum, including the microscopic sections that had been prepared by Mr. Carruthers and those of Count Solms-Laubach, which Dr. Scott of the Jodrell laboratory at Kew kindly permitted me to see, but I also made an excursion to the Isle of Portland, and examined the celebrated "dirt beds" from which the original specimens first described by Buckland in 1828 were obtained. On this excursion I had the great pleasure of being accompanied by Dr. Alfred Russel Wallace, and we were so fortunate as to find a specimen of *Cycadeoidea microphylla* Buckl. in one of the quarries. It had been

[1] Proc. Biol. Soc., Washington, Vol. IX, 1894. pp. 75–87.
[2] Bull. Torr. Bot. Club, Vol. XXI, No. 7, July 20, 1894, pp. 291–299.

GROUP OF 21 CYCADEAN TRUNKS FROM THE PURBECK BEDS OF THE ISLE OF PORTLAND.

removed from the immediate bed in which it was found and lay on the ledge of stratified rock almost immediately over the exposure. We subsequently met Mr. Joseph Sansom, superintendent of the quarries, who had been in the habit for a long time of laying aside any fossils that were taken from the quarries, and had placed a large number of objects of various kinds in a tunnel under Wide street between two quarries. Among these were a considerable number of cycadean trunks, some of them very perfect. We were much surprised to find this fine collection, of which nothing seemed to be known in London. On my return to America I represented this condition of things to the assistant secretary of the Smithsonian Institution, Prof. G. Brown Goode, and was able to give a rough estimate of what they would cost if purchased by the National Museum. Professor Goode warmly seconded my suggestion that they be ordered, and negotiations were immediately entered into for their purchase. The ultimate result has been that the entire collection, consisting of twenty trunks, is now the property of the United States National Museum. The specimen found by Dr. Wallace and myself was taken to his cottage in Parkstone, and when the shipment was made by Mr. Sansom, through the kindness of Dr. Wallace this specimen was included and arrived with the others. This group of twenty-one trunks has been photographed, and Pl. XCIX will afford a rough idea of a cycadean forest in Purbeck time. I have not yet had time to give this collection the careful study that it deserves, but it is certain that we have both the original species of Buckland (*Cycadeoidea megalophylla* and *C. microphylla*), and probably one or two other species. Most of them show the "crow's nest" distinctly, and those of the first-named species very closely resemble the original figured by Buckland.[1] None of the specimens of *C. microphylla* very closely resemble Buckland's figure (pl. xlix, fig. 1), and it may be said in general that the external surface in all these specimens is more obscure than his figures seem to indicate for the original ones. Most of them are of a light color, showing their contact with the limestone very distinctly, but in one or two cases they have the dark carbonaceous color of the "dirt beds." They are mostly much compressed vertically so as to appear squat and dwarfish. The smallest one is less than 3 inches high and more than twice that breadth. The one having the largest diameter, nearly 12 inches, is less than 4 inches high, and the large crow's nest makes a depression of nearly 2 inches on the upper side. This one was broken in transit into a number of segments, and the fracture affords the only opportunity I have had of examining the internal structure. Without polishing, the principal fact which it reveals is the course of the vascular bundles passing out from the center in fine white lines. There has not yet been time since the arrival of this collection for any sections to be cut or microscopic study made. They average considerably smaller than the specimens

[1] Trans. Geol. Soc., London, 2d ser., Vol. II, 1828, pl. xlvii, fig. 3.

mentioned by Buckland and Fitton. The former says that "In the fossil specimens yet discovered, it [the trunk] varies from 5 inches to a foot in height, and from 8 to 15 inches in diameter";[1] and Fitton says that "The Cycadaceæ found in the 'black dirt' are generally from 9 inches to a foot in diameter, and about 9 or 10 inches high."[2] The ten specimens in this collection that certainly belong to *C. megalophylla* range from 3 to 6 inches in height and from 5 to 12 inches in diameter. Six or seven specimens, including the one found by Dr. Wallace and myself, doubtless belong to *C. microphylla*, and have a somewhat different shape, being considerably higher in proportion to their thickness. These range from 5 to 9 inches in height and from 7 to 10 inches in diameter. The smallest specimen weighs 5 pounds and the heaviest 29¼ pounds.

I should add that there are two specimens that certainly do not belong to the two original species; one of them is very well preserved, and though flattened laterally has a symmetrical conical shape. It is 13½ inches high and the two diameters are respectively 6 and 9 inches. I have no doubt that it belongs to *C. portlandica* of Carruthers, and his fig. 1, on pl. lxi of his memoir,[3] is a fairly correct representation of it, although Mr. Carruthers was able to show more definite structure on the external surface than can be seen on this specimen. Still, so far as the markings are visible, they agree substantially with those of his figure. This specimen is readily distinguished from the rest in the group (Pl. XCIX) in rear a little to the right of the center. The other specimen is smaller and much less perfect, but probably also belongs to the *C. portlandica*, although its internal structure may possibly prove to be that of *C. Morieri* Renault sp.,[4] which it resembles externally. In that case the collection would contain all the species of Cycadeoidea that have ever been described from the Purbeck beds, except the rare *C. Carruthersi*, of which no figures have appeared to indicate its form. As already stated, I saw at the British Museum on the occasion of my visit the greater part of these species, and judging from the notes taken and from my recollection of their appearance the new collection is fully equal in variety and importance to the one from this locality in that museum, as the originals of Buckland's species are not there and seem to be lost. These specimens are of special interest in comparison with the American forms, of which a similar group is exhibited on Pl. C, from the Potomac of Maryland, and another on Pl. CI, from the Black Hills; but the English forms cut a sorry figure by the side of our gigantic trunks, the largest of which stands 31 inches in height, measures 26 inches in diameter, and weighs 721 pounds.

Besides the two old species of Buckland above mentioned, three

[1] Ibid., p. 397.

[2] Op. cit., Vol. IV, p. 222.

[3] On Fossil Cycadean Stems from the Secondary Rocks of Britain. Trans. Linn. Soc., Vol. XXVI, 1870, pp. 675–708, pl. liv–lxiii.

[4] Note sur le Clathrepodium Morieri, B. R. Bull. Soc. Linn. Normandie, 4e sér., Vol. I, Caen, 1887, pp. 143–151, pl. iv, v.

GROUP OF CYCADEAN TRUNKS FROM THE POTOMAC FORMATION OF MARYLAND.

GROUP OF CYCADEAN TRUNKS FROM THE BLACK HILLS OF SOUTH DAKOTA; LOWER CRETACEOUS.

others, as will be seen by the table, have been described from the Purbeck beds of Portland. Three of the species of Cycadeoidea are said to come from the Lower Greensand, including the celebrated *C. Gibsoni*, about which so much has been written, and which of all cycadean trunks exhibits the fruiting axes to the greatest perfection. In addition to these there is the *C. Saxbyana*, which is the only trunk thus far found in the Wealden proper. This is from Brook Point on the Isle of Wight, which is also the locality for the well-known fossil forest, of which I shall soon speak. All of these trunks it was my privilege to examine in the British Museum. There are three specimens of the *C. Saxbyana*, but the labels were not sufficiently full for me to determine whether they were all from the same locality. One of them has a terminal leaf bud, and all of them closely resemble some of the smaller trunks from the Black Hills. The *C. Gibsoni* is disappointing when seen from without, as only by close study can the arrangement of the leaf scars and flowering axes be made out, but this lack is more than compensated for by the wonderful display of minute internal structure seen in the sections and visible even to the naked eye. This is not, of course, the place to discuss this remarkable phenomenon, but the occurrence of well-developed seeds far in the interior of a solid trunk certainly gives rise to a great number of questions as to their true morphology. I also saw the *C. Peachii*, from the Coral Rag of Helmsdale, Sutherlandshire, Scotland, which does not come within the purview of this paper, but which, notwithstanding its greater age, strikingly resembles one of our most perfect Maryland specimens. Of *C. inclusa* I was able only to see a model, the original being in the York Museum. This is from the Lower Greensand of Potton, Cambridgeshire, but does not widely differ from the forms farther south. With regard to *C. Gibsoni*, from the Greensand of Luccomb Chine, and *C. maxima*, from Shanklin, on the Isle of Wight, there is room to suppose that, although found in the Greensand, which is alone exposed at these localities, they may have both originally come from the Wealden, lying directly under these beds. At times of very low tide the Wealden strata have actually been seen at the base of the Greensand at Sandown and some distance farther to the southwest, and a little above Sandown, as is well-known, it comes to the surface, and rises many feet at the Red Cliff. The range of the cycadean trunks in England is, however, much greater, some having been found in the Lower Lias of Lyme Regis, but thus far none have been found higher than the Lower Greensand, and possibly may not have lived later than the close of the Wealden period. Their history in America is almost precisely similar, one species, *C. Emmonsi*, occurring in the Upper Trias of North Carolina, and another, *C. abequidensis* Dn., from nearly the same horizon on Prince Edward Island, while all the rest are from the Lower Cretaceous, and confined to the lower portion of those deposits, the Maryland beds, those of the Black Hills, and probably the Cheyenne Sandstone of Kansas not being widely different in age.

FOSSIL FORESTS.

In point of interest the fossil forests of this period may, perhaps, claim the second rank. Those of the Purbeck beds are among the most celebrated in the world. They have frequently been described and graphically portrayed by the older geologists of England. As early as 1829 Mr. Webster said of them:

In it [the "dirt bed"] are found considerable numbers of fossil trunks of trees of the dicotyledonous class, which are from 1 to 2 feet in diameter. The woody part is siliceous, and the longitudinal vessels are filled by, and surrounded with, radiated quartz; numerous veins of chalcedony and quartz also pass through these stems, but always following the direction of the concentric and radial structure. In the cavities, and particularly on the outside, there is a small quantity of carbonate of lime; but this is only superficial, and has been a deposit subsequent to the silex. I saw one of these trunks standing erect, and the workmen informed me they were frequently found in this position. Its lower part was thickest, and being divided, it gave the idea of the commencement of roots; its upper part penetrated through the *soft burr* and terminated in the *aish*. The trunks are always broken off short, seldom exceeding 3 feet in length. This is the fossil wood which is so often brought from the Isle of Portland; and upon the most careful inquiry and examination, I could not discover that it was found in the oolite itself, nor in any other part of the series.[1]

Dr. Mantell, in his Geology of the Isle of Wight, which contains a chapter on the Portland beds, makes the following allusion to them as well as to the cycadean trunks:

Upon the uppermost oolitic stratum, is a layer a foot thick, of very dark brown, friable loam, which appears to have been a bed of vegetable mould. It contains a large proportion of earthy lignite, and, like the modern soil on the surface of the island, waterworn stones, and pebbles. This layer is called the *"dirt-bed"* by the quarrymen, and in and upon it are stems and branches of coniferous trees and plants allied to the *Cycas* and *Zamia*. Many of the trees and plants are standing erect, as if petrified while growing undisturbed in their native forest. Their roots extend into the soil of the dirt-bed, and their trunks into the superincumbent strata of limestone.

As the Portland building stones lie beneath these beds, and the *cap* is only used for lime, the fossil trees are removed and thrown by as useless, and the dirt-bed cleared away to arrive at the more valuable material. On one of my visits to the island the surface of a large area of the dirt-bed was exposed, preparatory to its removal, and the appearance presented by the fossil trees was most striking. The floor of the quarry was literally strewn with fossil wood, and before me was a petrified forest, the trees and the plants, like the inhabitants of the city in Arabian story, being converted into stone, yet still remaining in the places they occupied when alive! Some of the trunks were surrounded by a conical mound of calcareous earth, which had evidently, when in the state of mud, accumulated around the stems and roots. The upright trunks were in general a few feet apart, and but 3 or 4 feet high; they were broken and splintered at the top, as if the trees had been snapped or wrenched off at a short distance from the ground. Some were 2 feet in diameter, and the united fragments of one of the prostrate trunks indicated a total length of between 30 and 40 feet. In many examples portions of branches remained attached to the stems. The external surface of all the trees I examined was weather-worn, and resembled that of posts and timbers of groins and piers within the reach of the tides, and subjected to the alternate influence of the water and the atmos-

[1] Trans. Geol. Soc., London. 2d ser., Vol. II, 1829, pp. 41–42.

phere. There were no vestiges of the bark in a carbonized state, nor of the natural external surface of the stems, as in the prostrate trees at Brook Point in the Isle of Wight.

The cycadaceous plants occur in the intervals between the trees, and the dirt-bed is so little consolidated that I dug up with a spade several specimens that were standing erect, in the position in which they originally grew. . . . The specimens are called *"crow's-nest"* by the workmen, who believe these plants to be bird's nests, originally built by crows in the fossil trees, which have become petrified. The largest specimens are about 2 feet high and 3 feet in circumference.[1]

The trees stand in the part of the series immediately above the upper "dirt-bed," locally termed the "soft burr," and project up through the several overlying deposits; but the erect portion is always comparatively short, not often exceeding 3 or 4 feet. They have their roots in the dirt bed itself. I have reproduced (Fig. 68) the excellent section

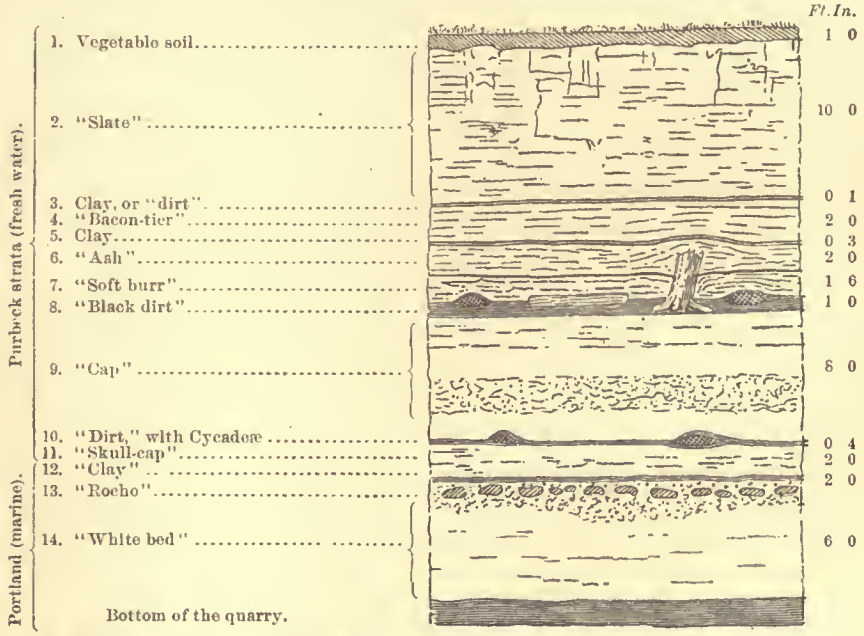


FIG. 68.—Section of one of the Portland quarries. From Fitton's Strata below the Chalk, 1835.

of Dr. Fitton, which was published in his celebrated paper on the Strata below the Chalk.[2] This section was made in 1834, but when I visited the quarries and made a rough sketch of one of the best exposures I found the most remarkable similarity in all the essential details to that which is represented in this section. As Dr. Fitton's section was prepared with much more care than mine, I have decided to reproduce it as practically representing the exact present state of things. He has introduced cycadean trunks at both the lower and upper dirt beds, where they are known to occur, and he also shows one of the erect trunks with its roots in the

[1] Geology of the Isle of Wight, London, 1847, pp. 395-398.
[2] Trans. Geol. Soc. London, 2d ser., Vol. IV, 1835, p. 219.

"black dirt," penetrating through the "soft burr" into the "ash," with a portion lying prone at its base; all of which is exceedingly true to nature. At the time of my visit none of these detached portions lay in position in the quarries, they all having been removed, but very short portions of the erect trunks still remained, from which I secured specimens. They were, however, too close to the roots to give the best results.

The specimens collected by us were from Kingbarrow quarry, and the cycad trunk above referred to lay on the same ledge only a short distance from the fossil stumps. There is every probability that it came from the dirt bed in which this trunk had its roots. In Mr. Sansom's tunnel under Wide street, besides the cycads and many other objects, there was an immense fossil trunk 26 feet in length and 4 feet in diameter at the lower end, diminishing to 2 feet at the upper end. At the extreme outer limit of the town of Portland proper, another fossil tree taken from these quarries has been fastened up against the side of a house. It was evidently taken out in sections, but in such a way as to admit of their being placed in their natural position one upon another so as to show nothing but the line of fracture. At the base it shows the enlargement preparatory to putting forth the roots. It is forked at the summit, the two branches being nearly equal, both in size, and in the length preserved. The house against which it stands is called the "Antediluvian House." It is No. 1 Fortune's Well street, Portland. We made a rough estimate of its height, and I recorded in my note-book that it was about 20 feet to the forks, and that the two branches were about 2 feet in length. It measured 11 inches in diameter above the enlargement at the base. On my return I found to my surprise that Dr. Fitton had described this same specimen in the memoir above referred to (p. 221), and in the following words:

> Some very fine specimens of the silicified trunks had been found not long before I saw them; one of which had been judiciously restored by joining the fragments and placing the whole erect against the wall of a house. The total height from one extremity to the other was above 20½ feet; the diameter of the stem where the roots went off, about 11½ inches. The trunk was nearly straight and undivided for about 17 feet, and the branches slight in comparison with the main stem.

It will be seen that our estimate of the height was a little too great, and his measurement of the base was probably made at a point slightly lower than ours. It is a somewhat remarkable fact that this specimen should have been permitted to remain in the same position for so long a time. It had probably been there some time before Dr. Fitton described it, which he did in 1834, or sixty years prior to our visit. Dr. Fitton describes and figures on the same page another very similar but somewhat larger specimen from the Dungeness quarry, from which the first was also taken. This shows the beginnings of the roots and is, he says, elliptical in cross section. The two agree, however, in the important particular of being forked at the summit by a true dichotomy, which is rare in trees of so large a size. This at once indicates a peculiar type of vegetation. I reproduce here (Pl. CII, Fig. 1, facing p. 498)

Dr. Fitton's figure. As will presently be seen, all the fossil wood from the English Wealden, including the Purbeck, is of the Araucarian type, and in the absence of other parts must be referred to the genus Araucarioxylon. Assuming these two trunks to belong to the same species, I propose for them the name *Araucarioxylon antediluvianum*, the specific name referring, of course, to the "Antediluvian House," against which one of the specimens stands.

The fossil forests of the Isle of Wight are very different from those of the Purbeck beds. The principal ones occur on the southwest shore of the island near Brook Point. They consist of loose trunks lying in a confused manner and bearing evidence of having been transported for some distance and stranded in their present position. They were first described by Mr. Webster in a contribution made by him to Sir Harry Englefield's Picturesque Beauties of the Isle of Wight, which appeared in 1816. Mr. Webster says:

> At Brook Point the cliffs interested me much. They were about 30 feet in height, and were composed chiefly of clay resting upon a bed of soft sandstone, which contained a considerable quantity of sulphur, arising from the decomposition of pyrites.
>
> At this place I observed many masses of a coaly blackness, bearing the exact form and resemblance of trunks of trees that had been charred, lying on the beach, and embedded in the clay cliffs, and also in the rock.
>
> In some parts the ligneous fibre was still evident. In other parts the wood had been converted into a substance much resembling jet; its blackness being intense, its cross fracture conchoidal, and its luster very great. Other parts of the trees were entirely penetrated by pyrites, and considerable groups of crystals of this substance were frequently attached to the outside.
>
> They were embedded in clay of various colors, white, gray, yellow, and red, and lay in irregular horizontal strata of several inches in thickness, being often pressed flat by the incumbent weight. Over this stratum of clay, which is about 8 or 10 feet thick, there is another of the same depth, of sand and gravel, highly ferruginous; and the water which filters from it is strongly impregnated with sulphate of iron.
>
> On lifting up some of the sea weeds which grew upon the shore between high and low water mark I was surprised to find almost all the rocks below them composed of petrified trees, which still retained their original forms. They were of various sizes, from 8 or 10 feet long and 2 feet in diameter to the size of small branches. The knotty bark and the ligneous fibre were very distinct; and they were frequently embedded in masses of clay now indurated and in the state of an argillaceous rock.
>
> Some parts of these trees were converted into ironstone, and other parts consisted of a great variety of substances, being partly calcareous, siliceous, ferruginous, pyritous, bituminous, and ligneous; and the whole exhibited a beautiful example of the astonishing processes of nature in converting vegetables into coal, and in filling their substance with solid rock.
>
> These changes have no doubt taken place at a period too remote for human conjecture, and whilst the trees were yet buried under the strata which still partially cover them; their present situation on the shore arises merely from the sea having made gradual inroads upon the land, and, after having washed away the soil above, exposed them to view.[1]

[1] A Description of the Principal Picturesque Beauties, Antiquities, and Geological Phenomena of the Isle of Wight, by Sir Henry C. Englefield, Bart.; with Additional Observations on the Strata of the Island and their Continuation in the Adjacent Parts of Dorsetshire, by Thomas Webster, esq., London, 1816, pp. 153–154.

In a paper read before the Geological Society of London on December 3, 1845, Dr. Mantell gives the following account of the fossil forests of the Isle of Wight:

The trees are lying confusedly one upon another. I saw no erect trunks, or any other indication that the forest had been submerged while growing in its native soil, like that of the Isle of Portland; but, on the contrary, the appearance; both of the trunks in the sand rock and of those exposed to view by the removal of the materials in which they were originally embedded, is that presented by the rafts that float down great rivers, as, for example, the Ohio and Mississippi. Such rafts entangle in their course the remains of animals and plants that may happen to lie in the bed of the river, and at length subside and are buried in silt and sand. The fossil trees in this cliff are associated with large river shells and with the bones of colossal land reptiles. The fossil forest at Brook Point we may therefore consider as a raft of pines which floated down the river of the country near which the Wealden beds were deposited, and had become submerged in the delta or estuary at its mouth, burying with it the bones of reptiles and the large freshwater mussels it had entangled in its course.

The trees when lying in the sandstone are invariably covered with their bark, which is now in the state of lignite, varying from 1 to 3 or 4 inches in thickness, according to the magnitude of the trunk. This carbonized cortical investment is quickly removed on exposure to the action of the waves, but the ligneous structure, the woody fibre, remains.

The trees are calcareous and not siliceous, like those of Portland. They are more or less traversed by pyrites, and the delicate veins and filaments of this mineral which permeate the woody fibre impart a beautiful appearance to the polished specimens, particularly to those which exhibit a transverse section of the stems. The trunks are generally of considerable magnitude, being from 1 to 3 feet in diameter. I traced two upwards of 20 feet in length, and these were of such a size as to indicate a height of 40 or 50 feet when entire. They appear to have attained maturity.

In the conversion of the bark into lignite and in the smooth condition of the trunks this fossil forest presents a remarkable dissimilarity from that of the Isle of Portland, in which, so far as I have observed, the carbonized bark rarely, if ever, occurs, and the surface of the stems is similar to that exhibited by the trunks of old decorticated trees that have been much weathered by alternate exposure to air and moisture. At Brook Point, on the other hand, the trees appear to have been engulfed when fresh and vigorous, and when their bark and vessels were full of sap. The annular lines of growth are often very distinct, and I have traced from thirty to forty on some of the stems, but these circles are unequal, and indicate therefore a variation from year to year in the climate of the country in which they grew. The wood exhibits, under the microscope, coniferous structure of the type seen in the *Araucaria* (Norfolk Island Pine), the rows of glands or ducts being placed alternately, and the appearance being similar to that of the fossil wood of Willingdon in Sussex. I observed no trace of the foliage of these trees, nor of their fruit, with the exception of a small cone, scarcely so large as that of the larch.

In the strata that overlie the fossil forest, thin interrupted seams and irregular masses of lignite are very abundant, and their substance is more or less impregnated with and permeated by iron pyrites. Fossils similar to these occur also in the clays of Tilgate Forest and at Hastings.[1]

Very little additional information has accumulated with regard to these fossil forests since that date, as may be judged from the follow-

[1] Quart. Journ. Geol. Soc. London, Vol. II, 1846, pp. 92-93.

ing statements contained in the second edition of Bristow's Geology of the Isle of Wight, 1889:

Below and partly imbedded in this rock lie the scattered trunks of coniferous trees, known as the "Pine Raft." They were first observed by Webster in 1811, but were more fully described by Mantell in 1846. The trunks lie prostrate in all directions, broken up into cylindrical fragments. They are covered by thin bark, now in the state of lignite, the wood having been converted into a black or grayish calcareous stone, with much iron pyrites. Many of the trees still present traces of woody structure, and the annular rings of growth are clearly perceptible, but they are traversed also by numerous threads of pyrites. The trunks are generally of considerable magnitude, being from 1 to 3 feet in diameter; two upwards of 20 feet in length, and of such size as to indicate a height of 40 or 50 feet when entire, were noticed by Mantell.

The "Pine Raft" can be seen at low water only. During spring tides it may be observed to rest on variegated marls, but all attempts to trace it eastwards from Brook Point have failed, probably on account of its being of local development only. The purple marls forming the cliff above it are apparently the same beds that have made the great slip of Roughland, and the "Pine Raft," if it is continuous, should be found in the cliff near Sedmore Point; but though many large fragments of trunks are lying on the beach, there is no bed in the cliff exactly corresponding to that of Brook Point.

As suggested by Mantell, the trees were probably drifted from a distance, in the same manner as the trunks, brought down by the Mississippi at the present day, are deposited in large rafts in the delta of that river. It is not to be expected, therefore, that the "Pine Raft" is of wide range, or that the horizon at which it occurs should be recognizable when the trees are not present. There is no evidence that any of the trees in this or any other part of the Wealden series grew upon the spots where they are now found.[1]

At the time of my visit to the Isle of Wight the "Pine Raft," though many of the logs lay above the water, was inaccessible except by boat; but a little farther to the northwest, viz, at Hanover Point, there was a collection of prostrate trunks, some of them lying on the strand and others at about the elevation of high tide, projecting from the cliff. They were of a very dark color and contained much pyrites, but were not incrusted with marcasite, as is much of the lignite of the Potomac formation. I collected specimens from four different trunks, selecting from the parts which seemed most likely to show internal structure. One of these specimens was surrounded by a pyritiferous envelope, which has almost completely effloresced, leaving a mass of comminuted material, flakes, and chips in the box in which it was contained, and an ashy-white substance on the surface of what remains. The other three specimens have not suffered at all from this process. One of them has a jet-black coat of coaly matter, with a shining surface, to which there adheres in some places blotches of pure iron pyrites of a green color. This black coating varies in thickness from one-third to one-fourth of an inch, and seems in places to be divided into two obscure layers. It is very light, like charcoal, and shows scarcely any structure. This outer coating is in marked contrast with the light ash-colored interior, and it

[1] The Geology of the Isle of Wight, by Henry William Bristow. Second Edition, Revised and Enlarged, by Clement Reid and Aubrey Strahan. London, 1889, pp. 6–7.

is easy to see how it might be mistaken for the bark of the tree, but I see no evidence whatever that such was the case, and regard it simply as an illustration of the fact that under the conditions to which these trunks were subjected the interior was petrified, while the exterior remained in the condition of lignite.

Internal structure.—Although, in the papers relating to the fossil forests of the Wealden and Purbeck beds, reference has several times been made to the evidence furnished by the internal structure as to the botanical character of the trees that compose these forests, and although from these statements it is certain that thin slices have been from time to time prepared and studied, still, so far as I can learn, no figures showing this structure have ever been published. Relative to the Portland trunks, Dr. Fitton makes the following remarks: "From the evidence afforded by thin transparent slices both of the transverse and longitudinal sections, which have been examined under the microscope by Mr. Brown, the fossil trunks of Portland are found to possess the characters uniformly belonging to coniferous wood; but it must be observed that these characters are not absolutely confined to Coniferæ." And in a footnote he says: "One of the longitudinal slices examined by Mr. Brown was broken from the extremity of the left branch of the tree represented in the annexed woodcut."[1] He does not state whether the "longitudinal sections" were made tangentially or radially. In the latter case it would not be true that the characters represented are not exclusively coniferous.

Dr. Mantell, speaking of the same trunks, makes the following statement: "Slices rendered transparent by Canada balsam exhibit under the microscope, in the transverse sections, the cellular tissue as a reticulation of polygonal meshes; and in the radial, the ducts or glands characteristic of the Coniferæ, and arranged in alternate rows as in the Araucaria or Norfolk Island Pine."[2]

The Wealden trunks from the Isle of Wight possess the same general character as shown by their internal structure. Of these Dr. Mantell says: "The wood exhibits, under the microscope, coniferous structure of the type seen in the Araucaria (Norfolk Island Pine), the rows of glands or ducts being placed alternately, and the appearance being similar to that of the fossil wood of Willingdon in Sussex."[3] Here again he fails to show by any published figures what the internal structure was as evidenced by his microscopic sections.

In view of this great lack of evidence upon the question of internal structure it is of the utmost importance that this aspect of the subject be brought out. The material which I obtained was very limited in amount and deficient in quality. I placed it in the hands of Dr. F. H. Knowlton and requested him to examine it. He did so, and indicated the most advantageous directions for cutting sections, and a number of

[1] Trans. Geol. Soc. London, 2d ser., Vol. IV, 1835, p. 222.
[2] Geology of the Isle of Wight, 1847, pp. 282-283.
[3] Quart. Jour. Geol. Soc. London, Vol. II, Dec. 3, 1845 (Proceedings), p. 93.

thin slices were prepared and mounted in Canada balsam. Dr. Knowlton has studied them, and while several of the specimens showed too little structure to be available, those from the Purbeck and one of the specimens from the Isle of Wight are sufficiently well preserved to form the basis of a report which he has placed in my hands. It is as follows:

DESCRIPTION OF TWO SUPPOSED NEW SPECIES OF FOSSIL TREES FROM THE PURBECK BEDS OF THE ISLE OF PORTLAND AND THE WEALDEN OF THE ISLE OF WIGHT, ENGLAND.

ARAUCARIOXYLON WALLACEI n. sp. Knowlton.

Pl. CII, Figs. 2–4.

Habitat: Isle of Portland, England; Kingbarrow Quarry. An erect stump in place in the "burr" overlying the upper "dirt bed" of the Purbeck. Collected by Lester F. Ward and Alfred Russel Wallace, August 17, 1894.

Diagnosis.—Rings of growth broad (4 to 7 mm.), very indistinct, the fall wood consisting of 6 or 8 rows of thickened cells; other cells uniform in size; wood cells long, pointed, provided on the radial walls with a single row of contiguous, large pores; medullary rays in a single series of 1 to 8 superimposed cells, not very abundant.

Macroscopic characters.—The fragment submitted is about 7 cm. in length and about 4 cm. in diameter. It is a segment from a small trunk that was probably 12 or 15 cm. in diameter. It is white in color, being perfectly silicified and somewhat distorted by irregular bands of bluish-white chalcedony which cut through it in various directions. The periphery of the segment is irregularly furrowed, as though it had partially decayed before fossilization.

Microscopic characters.—Thin sections when viewed under the microscope show that it is only fairly well preserved. The structure is made out with some difficulty, especially in the vicinity of the bands of chalcedony. In detail the following characters may be noted.

Transverse section.—It is not possible to distinguish the rings of growth with the naked eye, but under the microscope they are found to be present, although very faint. The rings are broad and the actual area of demarkation between them consists of only 6 or 8 layers of cells with thickened walls and diminished lumen. The ordinary cells, that is, those of the spring and summer wood, are of very uniform size and small. The rays in this section are seen to be rather few in number.

Radial section.—The section in longitudinal-radial direction is the most satisfactory of all. The wood cells are long, apparently pointed, but much distorted. In only exceptional cases are the pits preserved. They seem to be in a single series, which approximately covers the wall. They are too obscure to permit their size or the size of the inner pore to be made out with certainty.

Owing to the distortion it is possible to get only a very small area of the medullary rays in the plane of section. Nothing can be made out regarding either their length or markings.

Tangential section.—This section is reasonably satisfactory. It shows the medullary rays to be in a single series from one to eight or ten cells high, the average number being from three to six. They are not numerous, for there are often two or three contiguous wood cells that do not show rays within the range of a microscopic field.

From this description it is not possible to make out with absolute certainty the proper generic reference. The most important character, viz, the punctations on the radial walls of the wood cells, is so obscure that some uncertainty results. Yet these punctations, if correctly observed, are seen to be in a single contiguous series, which nearly or quite covers the wall. This is a character of the genus Araucarioxylon, and I have so considered it. Subsequent investigation of material better preserved may throw additional light on the matter.

ARAUCARIOXYLON WEBBII n. sp. Knowlton.

Pl. CII, Fig. 5.

Habitat: Hanover Point, Isle of Wight, England. Fossil wood from prostrate logs at foot of cliff above tide. Wealden. Collected by Lester F. Ward and E. A. Webb, August 19, 1894.

Diagnosis.—Rings of growth absent; wood cells large, thick-walled, of uniform size; wood cells with a single series of contiguous pores; medullary rays in a single series of from 1 to 30 cells high, abundant.

Macroscopic characters.—The specimen submitted is a fragment about 10 cm. long, 5 cm. wide, and 3 cm. thick, and appears as though broken from a log of some size. It is dark, almost black in color, with a coaly outside layer 4 mm. thick. This coaly layer is crusted in many parts with a thick layer of iron pyrites. The specimen is thoroughly silicified and much distorted by secondary crystallization. It is traversed in various directions by white bands of calcite.

Microscopic characters.—The distortion of the tissues by the processes of crystallization has been so great that the microscopic characters are made out with difficulty.

Transverse section.—(See fig. 5). This section is by far the best one. The wood cells are of uniform size, with thick walls. There is no evidence of annual rings. The medullary rays are numerous as seen in this section, and have thick walls.

Radial section.—This section is especially unsatisfactory. The plane of section is so much interrupted that no adequate idea can be gained of the appearance of the medullary rays. The same might almost be said of the punctations on the wood cells, yet by careful selection it appears that they are in a single contiguous series, which does not cover the entire wall. Their size can not be determined. The inner pore is also too obscure to admit of measurement.

Tangential section.—This is obscure, yet shows in exceptionally well-preserved places that the rays are numerous, thick-walled, in a single series, and usually some twenty or more cells high.

At my suggestion and request Dr. Knowlton has given to the species from the Purbeck beds of Portland the name *Wallacei*, in honor of Dr. Alfred Russel Wallace, the celebrated traveler, scientist, and philosopher, who, as above stated, accompanied me and assisted in collecting the specimens. Similarly he has given to the specimen from the Isle of Wight the name *Webbii*, in recognition and remembrance of the delightful companionship of Mr. E. A. Webb, which I enjoyed on the occasion of my visit to that island, and who showed me not only where the fossil forests were to be found, but many other interesting things which I would otherwise have failed to see.

It is surprising that no one in England has thought to describe or name these fossil woods, and I would not have ventured to do this on the imperfect material in my possession if it had not seemed to be the only way in which they could be brought into their systematic position as an integral part of the fossil flora of the Wealden.

PLATE CII.

PLATE CII.

Page.

FIG. 1. Araucarioxylon antediluvianum, Purbeck beds, Isle of Portland..... 490

FIGS. 2–4. Araucarioxylon Wallacei Kn., Purbeck beds, Islo of Portland..... 495

Fig. 2, radial section.

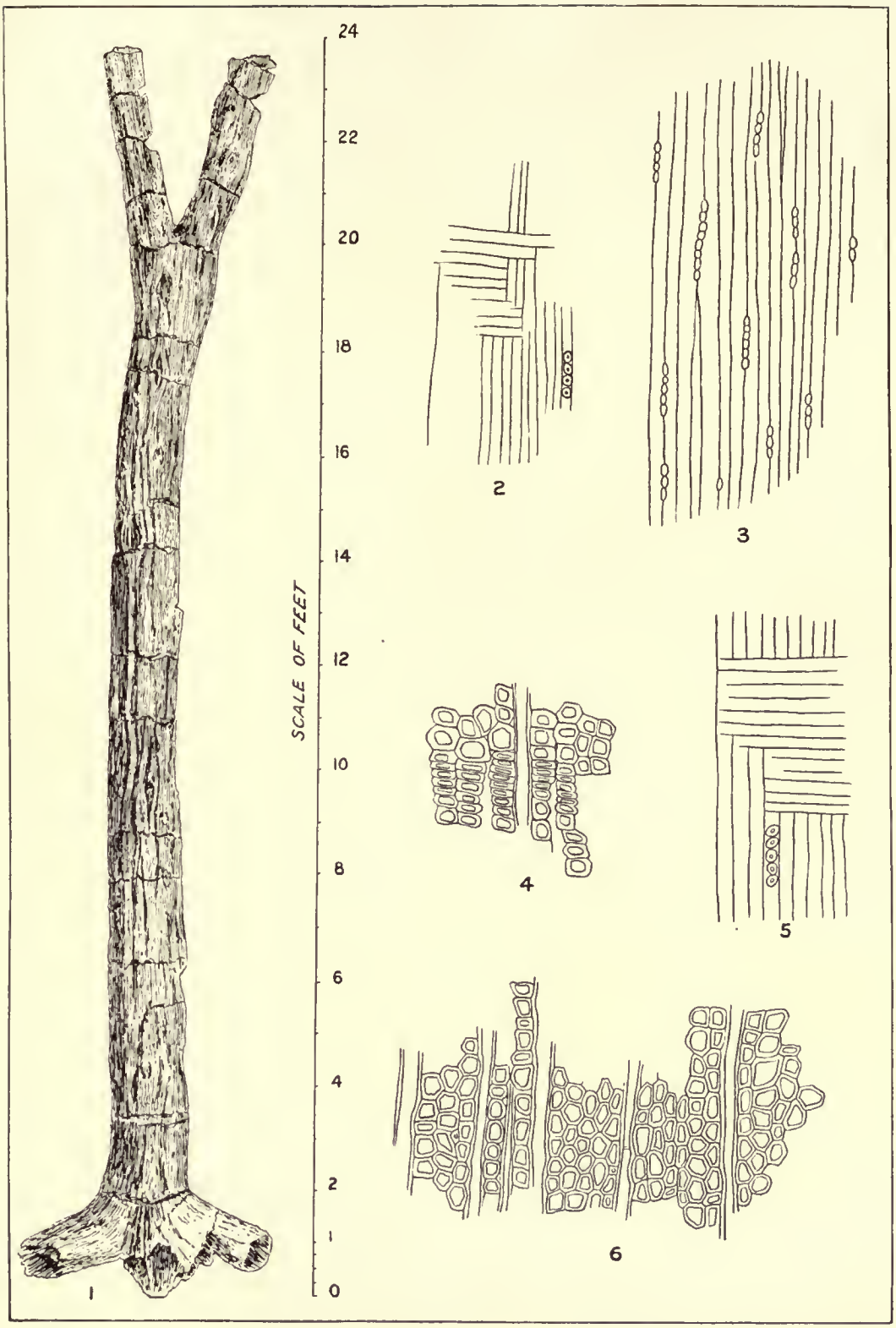
Fig. 3, tangential section.

Fig. 4, transverse section.

FIGS. 5, 6. Araucarioxylon Webbii Kn., Wealden deposits, Isle of Wight..... 496

Fig. 5, radial section.

Fig. 6, transverse section.



PETRIFIED WOOD FROM THE ISLE OF PORTLAND (PURBECK) AND THE ISLE OF WIGHT (WEALDEN).

As will be seen by the table, in addition to these specimens from the Purbeck and Wealden beds, "coniferous wood" has been reported from the Atherfield beds, the Lower Greensand, and the Gault. I have placed all these under one entry as "coniferous wood," although it will probably be found when they are subjected to scientific investigation that they represent several species and possibly more than one genus. It will be observed that while the structure of all the fossil wood thus far reported from the Potomac formation is of the Sequoian type, that of the Wealden deposits is of the Araucarian type. In America the Araucarian type is the only one that has thus far been detected in the Triassic deposits, either those of the Atlantic border (Connecticut Valley, Richmond and North Carolina coal fields) or those of the Southwest, the Shinárump formation of Major Powell. The celebrated Arizona woods, which yield such beautiful material for decorative objects, often show very perfect internal structure, and Dr. Knowlton, after examining a large number of specimens, was able to make only a single species, *Araucarioxylon arizonicum*,[1] which may be the same as the *Araucarites Möllhausianus* Göpp. described, but not figured by Göppert in Möllhausen's Reise (p. 492) in 1858, from specimens collected in the Rio Secco, near the Colorado Chiquito, Arizona, in 1853.[2] Those consulting Dr. Knowlton's description of the fossil wood and lignite of the Potomac formation[3] will observe an apparent exception to the statement made above. The *Araucarioxylon virginianum* is described by him as from the Potomac formation at Taylorsville, Va. A subsequent investigation of this locality by Mr. McGee, Professor Fontaine, and myself has proved that the fossil forest bed from which this specimen was taken really belongs to the Older Mesozoic or Upper Trias. This is one of the few regions in which the Trias and the Potomac formation are in contact, and without such a careful investigation as we made on that occasion it might be easy to confound these deposits, as the locality for the fossil wood lies close to the line of contact. It should, however, be remarked that some specimens of fossil wood collected by me in the Black Hills of South Dakota, at the same locality at which the great cycadean trunks occur, clearly exhibited the Araucarian structure. This locality is certainly Cretaceous, and therefore we have both types of structure in the Cretaceous of America.

I have dwelt thus fully on the fossil wood, partly because it is of great historic as well as scientific interest, and partly in order to emphasize the fact that, thanks to the labors of Nicol, Witham, Williamson, Renault, Felix, Knowlton, and other cultivators of this field, the vast quantities of petrified wood found at so many geological horizons and often constituting the only paleontological evidence of the

[1] New Species of Fossil Wood (*Araucarioxylon arizonicum*) from Arizona and New Mexico. Proc. U. S. Nat. Mus., Vol. XI, 1888, pp. 1-4, pl. i.

[2] Tagebuch einer Reise vom Mississippi nach den Küsten der Südsee, von Balduin Möllhausen. Leipzig, 1858.

[3] Bull. U. S. Geol. Surv., No. 56, Washington, 1889. (See p. 50.)

age of formations, is no longer the useless rubbish that it was formerly thought to be, and that in so far as it can furnish evidence that evidence is of the clearest and most reliable character.

The foregoing remarks, taken in connection with the table of distribution upon which they are based, render it obvious that the paleontological relations, especially those furnished by the plant remains, between the Wealden of England and the Potomac formation of the United States, and also more generally between the Lower Cretaceous of England and that of America, are as close and as much deserving of attention as are the geological relations treated at the beginning of this paper.

THE SCALY CLAYS OF ITALY.

Scarcely anything is said in the general works on the geology of Europe about the existence of the Cretaceous formation in Italy. It is entirely ignored in Geikie's Text Book of Geology and in the latest edition of Phillips's Manual of Geology. Little more can be said for Lapparent's Traité Géologique. In the second edition of that work (p. 1159) he treats the Scaly Clays under the Eocene system, and cites M. Mantovani[1] to the effect that it is tufaceous mud derived from below and sometimes contains blocks torn from more ancient formations. In another place (p. 1337) he speaks of their association with the *gabbro rosso*. Nevertheless a number of Italian geologists (De Stefani, Seguenza, Capellini, etc.) have recognized that formation within the last fifteen years. In a memoir by Capellini, which appeared in 1880,[2] he showed that Cretaceous rocks had been confounded with Eocene and Miocene ones, and referring to this paper in a later one, published in 1884,[3] he says (p. 536):

> As regards the Scaly Clays, I continued to maintain that they were of different ages. I recognized as Cretaceous rocks the sands of San Martino and Salto di Montese, with Inocerami and cephalopods, and in default of decisive facts I did not say the last word as to the chronological value to be attributed to the Ammonites of the neighborhood of Porretta, and concluded that it could be maintained at that date that they were proofs of the Cretaceous in the Apennines of Emilia.

Six years later the same author described a saurian fossil under the name of *Ichthyosaurus campylodon* from these same clays, and also treated of certain cycadean trunks out of the same beds in the Province of Bologna.[4] The saurian fossil was regarded as ample proof of the Cretaceous age of the strata in which it was found. In concluding his remarks upon it he says (p. 444):

> The fossils collected in the Scaly Clays of Emilia and of other parts of Italy have shown that in part they relate to the Senonian, but that there are also representatives of the Turonian, and that a great portion is certainly to be referred to the

[1] Atti Soc. Ital. Sci. Nat. Milano, Vol. XVIII, 1875, pp. 28–62.

[2] Il macigno di Porretta o le rocce a Globigerine dell' Apennino bolognese. Mem. Real. Accad. Sci. Ist. Bologna, Ser. IV, Tom. II, Bologna, 1880, pp. 175–194.

[3] Il Cretaceo Superiore e il Gruppo di Priabona, op. cit., Tom. V, Bologna, 1884, pp. 535–550.

[4] Ichthyosaurus campylodon e tronchi di Cicadee nelle Argille Scagliose dell' Emilia, op. cit., Tom. X, Bologna, 1890, pp. 431–450 two plates.

Cenomanian. It is probable that specimens have also been discovered from the Infra-Cretaceous, and it is also probable that in general the Cenomanian Scaly Clays rest upon the Triassic rocks in the Northern Apennines.

The cycadean trunks described in this memoir were not supposed to furnish in themselves definite evidence as to their age. This part of his memoir is devoted especially to giving an account of a fine one collected in the Scaly Clays in the Province of Bologna. The following is the substance of that account:

In the last days of November of the past year (1889) Signor Count Francesco Massci announced to me that he had collected in the Scaly Clays of the valley of the Idice, not far distant from his villa at Ozzano, certain stones which he suspected might be fossil cycads. Having been kindly invited to do so, I immediately repaired to his house in Bologna and ascertained that he really had reference to a wonderful specimen of a true cycadean trunk, but which had unfortunately been broken in order to enable him more easily to get it out of the field where it had been dug up. The Count having himself collected these important remains, kindly offered to guide me in exploring the locality, where I hoped to find some more fragments; in fact, on the 3d of December I went to Ozzano, and going up the right branch of the Rio Centonara, which traverses an important mass of typical Scaly Clays, 280 meters above the level of the Adriatic, the spot was pointed out to me where the fossil cycad had been exhumed. Count Massei related to me that on the 24th of November, in company with his foreman, Enrico Ghini, and Corporal Lucio Rocca, passing near an estate called La Torre, the property of Signor Engineer Cavalieri, in the parish Settefonti, on the road along the borders of a recently plowed field he found the four fragments of a cycad, which he recognized without difficulty as belonging to one and the same specimen.

I was then in condition to assure myself of the exact source; having succeeded, with careful search, in finding some additional pieces of the beautiful fossil, which, from its most perfect state of preservation and from the matrix which still adhered to it, permits me to exclude even the remotest doubt that it was just where it fell to the bottom of the Cretaceous sea before it became fossilized.

This, then, is the first fossil cycadean trunk collected under such favorable conditions as to permit us to affirm with certainty once for all that the fossil cycads collected loose in the streams of Emilia incontestably come from the Scaly Clays, and these also serve to prove that the Scaly Clays in which they are entombed belong to the Lower Cretaceous.

In intimate connection with this description he very appropriately makes mention of another specimen discovered in the eighteenth century, which is now lost, but relative to which an extensive memoir by Giuseppe Monti is extant, including a figure.[1] A file of the Commentarii is preserved in the library of the University of Bologna, and Capellini was able to consult it. He saw at once from the figure of Monti, who had regarded the fossil as a heap of barnacles, that it was a cycadean trunk, and on comparing it with the one recently found he observed that they were similar in many respects. The following is his account of the manner in which he came to recognize this ancient figure and of his researches in bringing the subject to light:

In 1865, when treating of the fossil Balænidæ of the Bolognese, I made known the fact that the first notices relative to remains of fossil Cetaceans were due to the

[1] De quadam Balanorum Congerie. De Bononiensi Scient. et Artium Instituto atque Academia Commentarii, Tomus tertius. Bononiae, MDCCLV, p. 323.

Bolognese naturalist Giacomo Biancani, who, at the end of 1757, described and figured vertebræ and remains of Balænidæ in his memoir published in the fourth volume of the Commentarii of our Academy under the title: *De quibusdam animalium exuviis lapidefactis.*

Two years before, in the same volume of the Commentarii, Giuseppe Monti published in the Opuscoli a work of his with the title: *De quadam balanorum congeries*, and this work was illustrated by a plate drawn and engraved by the celebrated Ercole Lelli. A specimen collected in 1754 in a stream which is an affluent of the Idice under Castel de' Britti was found in a collection of Count Giuseppe Ippolito Grassi, and was sent by him to Monti for study. Monti saw in it the form of a pine cone, and at first suspected that it was an ornamental relic of some ancient building, but having shown it to B. Beccari was assured by him that it was a fossil. It was then that Monti thought of barnacles, and imagined that it might be a great mass of the remains of these animals, so he called it *lapideorum balanorum insignis congeries*, describing it accurately and comparing it with other specimens of barnacles, with which, however, he found that he could not in any way identify his large specimen. It is sufficient to read that description in order to perceive that it might very well adapt itself to a specimen of a cycad of the same species as the one found by the Count Massei, and equally fossilized.[1] I suspected that it was a cycad the first time that, when engaged on these fossils, I recalled the plate with fossil barnacles published in the old Commentarii.

At the conclusion of his paper he says: "Some transported fragments may have been found in the Post-Cretaceous conglomerates, but the original bed is in the Lower Cretaceous."

In 1892 appeared the important memoir on the Cycadean Trunks of the Italian Museums, of which Capellini wrote the historical and geological parts and Count Solms-Laubach furnished the botanical descriptions.[2] This work was largely stimulated by the discoveries above recorded. For an indefinite period specimens of cycads had been accumulating in the various museums of Italy, and Senator Capellini conceived the idea of getting this material all together and having it systematically elaborated. Count Solms had long been engaged in the study of the English material, and was well qualified to do the botanical part of the work. Capellini's historical introduction is very thorough, and forms a most interesting document. For the present I can only refer to his matured conclusions relative to the age in which the Italian cycads flourished. The numerous specimens that had been picked up from time to time mostly upon the surface furnish no positive proof upon this point, but on investigating the subject he came to the conclusion that, notwithstanding the fact that most of them had been referred by different geologists to a much later period, all the specimens were probably originally derived from the Scaly Clays and had been transported and redeposited by various agencies in the beds where they were found. The case already mentioned was almost the

[1] It is not entirely improbable that the terminal portion of the cycad trunk found by Grassi was a part of the trunk of the specimen discovered by Count Massei, collected a short distance from the Castel de' Britti. In its measurements it corresponds to the missing upper part of the specimen recently found. [Footnote by Capellini.]

[2] I tronchi di Bennettitee dei Musei Italiani. Notizie Storiche, Geologiche, Botaniche, dei Professori Senatore G. Capellini e Conte E. Solms-Laubach. Con cinque tavole, (Mem. Real. Accad. Sci. Ist. di Bologna, Ser. V, Tom. II, Bologna, 1892, pp. 161–206, pl. i–v.)

only one in which they were actually found embedded in these clays; but a careful study of the surrounding conditions in nearly all the other cases showed that the clays were not far distant, and that such a secondary deposition would be very natural under the circumstances. He was struck by the close resemblance of these clays to the descriptions contained in American works of the beds in which the cycads of Maryland occur, and he concludes his account with the following remarks:

In May, 1859, Mr. Tyson had found two trunks of silicified cycads coming from the variegated clay of the Potomac group, Jurasso-Cretaceous formation, which he regarded as corresponding in part to the Wealden and in part to the Purbeck of English authors.

The specimens given to Tyson by Dr. Jenkins and Mr. Emack were found, the first near Contee Station and the second near Beltsville, and were deposited in the Museum of Baltimore. From the same clays, near Contee, Tyson obtained important specimens of saurians dug out of an iron mine, and through these the chronological correspondence could be better determined. The discovery of Tyson (recorded by Dana in his Manual of Geology, speaking of Cretaceous plants) was also mentioned by Carruthers, who, through the aid of Dr. Dawson, who possessed a photograph of those fossils, referred them without doubt to the genus Bennettites, with scales a little smaller than those of *B. saxbyanus*.

Fontaine, creating without necessity the new genus Tysonia, distinguished the fossil cycad of the Potomac with the name of *Tysonia marylandica*, referring to it the two above-mentioned trunks and the fragments. The descriptions and figures are accurate, but in default of any kind of sections we think it impossible to enter into a discussion relative to their more intimate relations with any of our Cycadeoideæ.

The interesting fact which it has pleased me to note is that there is an almost perfect chronological correspondence and a very great lithological similarity between the beds of the Cycadeoideæ of Emilia and those of the Cycadeoideæ (Tysonia) of Maryland. A part of the variegated clays of the Upper Potomac corresponds very well with our Scaly Clays, of which it sometimes even presents the fragmentary and scaly[1] character; and while, as to their fossils, the variegated clays of the Upper Potomac are made to correspond to the Cenomanian of Europe, it is also to be noted that even in America there is a species of hiatus in the superimposed chronological series, and that the Eocene or Oligocene immediately covers these clays. In the Lower Potomac sandstones and ferruginous sands, sometimes true conglomerates predominate, and they are considered to be of the age of the Wealden, and it is presumed that the abundant specimens of Cycadaceæ and other Cretaceous plants of the upper member are derived from these.

In working up the collections of cycads from Maryland and the Black Hills I had, of course, familiarized myself with the memoirs of Capellini, and had become deeply interested in the large amount of similar material existing in Italy, derived, as it thus seems, from beds so closely analogous to our own. Fourteen species are described by Solms-Laubach, and from Capellini's account it appeared that the greater

[1] I was at first inclined to translate the Italian term "argille scagliose" by the English *clay shales*, the more because, as stated above, I observed that where undisturbed they consist of shales; but in default of any allusion to them in English works I was very much in doubt as to the idea implied in the Italian designation "scagliose" (literally *scaly*). M. Lapparent generally contents himself with using the Italian term, but in one passage (Traité, p. 1159) he refers to them as "argiles écailleuses," which is not the French term for shales. I conclude, therefore, that the scaly character must have some reference to the peculiar appearance of the disturbed portions as described above. There is very little to justify Capellini's comparison of it to anything in the American beds.

part of all this material was at the University of Bologna in the geological museum. I therefore resolved, while on my vacation abroad, to visit Bologna if possible and examine these specimens. I was in correspondence with Senator Capellini, and before leaving America received from him a very courteous invitation to do so. This visit I made in the early part of September and enjoyed the fullest opportunities for satisfying my desires in this respect. My plan involved something more than merely to examine the material in the collections. Ozzano, near which place the large trunk, *Cycadeoidea Masseiana*, was found, is only a short distance from Bologna, and I expressed to Senator Capellini an ardent desire to make an excursion to this locality. This request was complied with in a manner that far exceeded my anticipations, for not only was I permitted to accompany the eminent Italian geologist to the place, but he had taken the pains to anticipate my arrival and to announce our coming to Count Massei, who discovered the specimen on his own estate and for whom it was named. It is needless to say that we were cordially received, and the Count accompanied us on the excursion over the Scaly Clays and pointed out to us the precise spot from which the specimen had been plowed out of the ground. The opportunity for examining the beds was all that could be desired. Count Massei after having discovered the specimen had frequently revisited the place and made careful observations in the vicinity. He had had the ground excavated in all directions and had found a few additional fragments. This work had been so thoroughly done that it was not of course to be expected that anything additional would be found on that occasion. But as I had seen the specimen at the museum this was a comparatively unimportant consideration. What I specially desired was to see the beds in which it had occurred and to make a general survey of the field.

The Scaly Clays present a very peculiar appearance; the rock has some resemblance to certain Potomac strata, but seems to consist chiefly of greatly disturbed and subsequently decomposed shales of a dark color, weathering whitish. At places there are ledges of these shales which are not decomposed, and these have the consistency of hard rock. They bear evidence of having been subjected to heat and sometimes have a tendency to be converted into slate. I was informed that fucoidal remains had been found in them and that *Chondrites intricatus* Sternb. had been described from them. They are probably of marine origin and intrusive rocks, probably gabbro, are mingled with them in irregular ways. Much pyrites and manganese and also crystals of calcite occur. It may be described as a calcareous sandstone, but very argillaceous. The region about Ozzano is very hilly, and the locality where the cycad was found is on the slope of a ravine leading down to the Rio Centonara. Everywhere on these slopes there has been extensive erosion of the decomposed shales, and the materials thus removed from their original position have a very different appearance from those

in place. Notwithstanding the heterogeneity of the rock the erosion is practically uniform, and the sculpture has the same regular character that is always seen where soft homogeneous material has been subjected to the action of the elements, as in the case of the Columbia brick clay of the Potomac Valley. But the Scaly Clays when thus eroded assume a very dark color, appearing nearly black at a distance. The uneroded portions are much affected with slickensides. In some places the eroded, and even occasionally the uneroded, material takes on a red color and even assumes the peculiar mottled appearance so characteristic of the Potomac clays, and which was also remarked in the Wealden of the Isle of Wight. I would not lay too great stress upon this phenomenon, but after all it is one which is not exactly paralleled at any other horizon in any part of the world so far as I have been able to learn.

High up on the slopes of these hills the Cretaceous clay is seen to be unconformably overlain by Pliocene sands and sandstones, which contrast with it in a marked manner.

While at Bologna I of course paid special attention to the great collection of cycad trunks in the geological museum. The greater part of those described by Solms-Laubach are, as already stated, in this place, and many of his microscopic slides were also there. The great *Cycadeoidea etrusca* Cap. & Solms, which, as I have stated in a former paper,[1] is not only the largest but also the most ancient, so far as human knowledge is concerned, of all the Italian cycads, having been found on a tomb in the Etruscan Necropolis at Marzabotto, in the province of Bologna. Its original source is of course unknown, and Capellini believes that it was designed as an ornament or symbolic emblem. On many of the tombs large stones were found, having of course the same purpose, but this was the only one that proved to be a cycadean trunk. It is black on its external surface, but has been cut through transversely and longitudinally, the longitudinal section passing through the center. The cut surfaces have been polished, and the nature of the stone is such as to admit of this admirably. The portion represented on pl. iv of the memoir referred to is only a small part of this longitudinal section, but the details can be seen even better in the original than in the figure. There are also radial sections of fragments, and the model that has been made of the whole section, though very perfect, has not been colored. The exterior of the specimen shows large elongated or elliptical flower buds or axes of inflorescence, and also small ones; the leaf scars are subrhombic in shape, but with rounded angles, so as to appear almost elliptical.

There are a number of specimens of *C. Capelliniana*, which is the one that has been found at the largest number of localities. I was unable to detect the presence of axes of inflorescence on the surface of any of the specimens. The ramentum walls are unusually thin. These specimens are also dark colored.

[1] Proc. Biol. Soc., Washington, Vol. IX, 1894, p. 84.

C. Massciana shows an abundance of flower buds, some of which project beyond the general surface. They have small perforations, being probably the scars of the surrounding bracts. These are features which are not well brought out in either of the figures published in Capellini's memoir.

C. Maraniana is too much worn to show the external characters distinctly. There are large openings on the surface which I would regard rather as indicating the existence of secondary axes or lateral branches than as flower buds. The cortex is unusually thick, even for cycad trunks, and the woody zones which it surrounds are much decayed.

The original specimen of *C. intermedia* scarcely justifies the definite structure shown on pl. iii, fig. 5. The scars are not depressions, but are level with the partitions, which, as the figure shows, are whitish on the general black ground. This specimen has been cut through longitudinally, and I am surprised that the inner surfaces were not figured in the memoir.

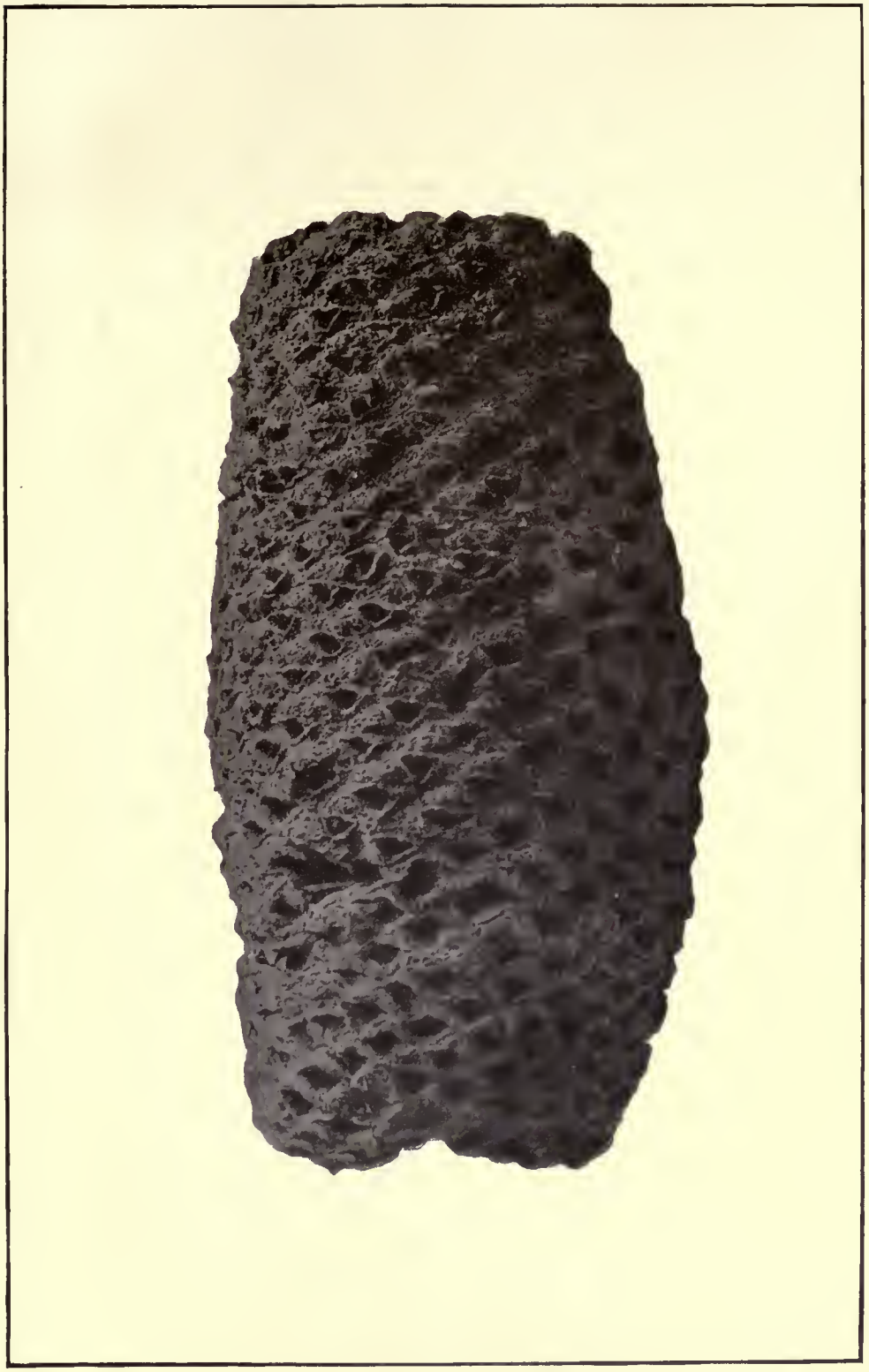
C. Pirazzoliana shows scarcely anything when viewed from without. Only the upper portion of the internal structure exhibited on pl. ii, fig. 1, was at the Geological Museum, but it fully justifies the figure.

C. Bianconiana shows the flower buds with large decayed centers much more clearly than would be supposed from the figure given (pl. ii, fig. 2).

Of *C. Scarabellii* only a model is to be seen in the Geological Museum, and this seems to be of the opposite side from that represented on pl. iii, figs. 2 and 3, and does not show the fine flowering buds seen in fig. 2, being much worn on that side. One large bud, however, was present, resembling the largest one shown in the figure. The polished surface of the cut brings out the structure very clearly, even more so than fig. 3, which was, of course, drawn from the original.

Also in the case of *C. Cocchiana* only a model could be seen. As no figure was given of the exterior of this fossil I would have been glad to see the trunk itself. From the model I judge that the outer parts had suffered much from wear.

Count Solms made a new genus for a peculiar fragment found near Imola and called it *Cycadea imolensis*. I examined this fragment, and found that it had no external parts whatever, so that its relation to the remaining trunks must be judged entirely by the internal structure. It has been cut in three oblique directions, chiefly transverse. It seems to be a portion in the vicinity of a branch or near the forks of two branches, and shows two axes. A superficial examination would never suggest that it was a cycad, but Count Solms found ramentum hairs which differed in their structure and form from those of any cycad hitherto examined by him, and chiefly upon the strength of this he described it as a cycadean trunk and gave it this name. I still think it was unwise to do this, since the creation of a new genus should certainly be based on abundant material.



CYCADEAN TRUNK (CYCADEOIDEA MASSEIANA) FROM THE SCALY CLAYS OF ITALY.

PLATE CIV.

PLATE CIV.

Page.

FIG. 1. Cycadeoidea Montiana Cap., Scaly Clays of Italy 509, 510

FIGS. 2, 3. Barnacles used for the purpose of comparison..... 501, 502
(Copy of figure of Monti., 1755.)

CYCADEAN TRUNK (CYCADEOIDEA MONTIANA) FROM THE SCALY CLAYS OF ITALY.

In looking over a large collection of cycads, such as that at the Geological Museum of Bologna, after having so long studied those of America, I could not fail to be struck by the general resemblance that holds among the forms in both countries, and considering the additional fact that both in America and England the remains of this class of vegetation are confined to the lower portion of the Cretaceous and older deposits, I can not help feeling that the paleontological evidence alone in favor of the Lower Cretaceous age of the Scaly Clays of Italy is strong. It does not appear that the animal fossils distinctly contradict this view, and as to the stratigraphy, a formation lying unconformably between the Trias below and the Pliocene above, may certainly be referred to any intermediate horizon which its flora and fauna require.

In view of the fact that *C. Masseiana* was actually found in the Scaly Clays and that I have myself examined the locality, I have thought it worth while to reproduce the figure that appears in the earlier of Capellini's two papers (see Pl. CIII). As Capellini inclines to believe that the original specimen of Monti may have formed a part of this same trunk, this also acquires peculiar interest. Capellini had the great kindness to hand me, on my departure from Bologna, the original plate published by Monti in the Commentarii, which he took from a duplicate volume in his possession. I have therefore thought best to reproduce the figure as it appears on that plate (see Pl. CIV). The following is the original description given by Monti, translated from the Latin:

Its length in one direction is 7 inches, or about half a Parisian foot; but in the other direction it scarcely equals half a foot, which measurements are about the same as in the rest of its parts; for its form approaches roundness moderately compressed; but at the summit, where there is a flat space, even slightly concave,[1] it does not exceed 4 inches in width. Its base, in whatever direction measured, is found to be 7 inches; therefore the circumference of the whole stone near the base would be almost two feet, but at the summit only 18 inches. Moreover, as regards the external form, although, as was stated, it may not improperly be compared to a truncated pine cone, yet it seemed to us rather to be not unlike a sailor's cap, although we could assert nothing with certainty concerning the base, since it appears to be broken and irregular on all sides. The material or substance, as well internal as external, of this stone is homogeneous, and indeed does not differ much from that of siliceous or igneous rocks, which are sometimes found to be of a dark or black color; for if it is struck at any place with flint it emits sparks. Nevertheless it has this peculiarity, that it is altogether opaque, and if broken is not smooth like flint, but shows in many places streaks interspersed with white crystalline particles; nor is there wanting metallic matter mixed with it, for in various places small shining lines are detected imitating copper pyrites. Its dark color and very great weight, exceeding 30 pounds, sufficiently convinced me when examining it that this stone also contains iron; so that it would not be surprising if it should be regarded by some as a lump of iron ore.

Senator Capellini, after having worked up the literature of the subject, undertook to rediscover the locality at which the specimen was

[1] The concavity observed by Monti and clearly expressed in the figure corresponds to the decayed portion noted by English authors in the trunk of Bennettiteæ referred to the genus *Mantellia* and described under the name of *crow's nest*. [Note by Capellini, loc. cit., p. 165.]

found. He made an excursion into the region, of which he gives the following account, which has considerable geological as well as historical interest:

In June last (1891), in company with Signor Count Francesco Massei and Signor Bernardi, now proprietor of the foundry, I visited the Rio della Cavaliera, following it up a good distance to familiarize myself with the nature of those clays and of the minerals that are met with.

The Rio della Cavaliera empties on the right side of the Idice, near the Molino delle Donne, and almost opposite the Cassola Canina. At the very entrance of the Rio, a short distance from Bernardi's house, there was found an interesting mass of limestone, containing *Lucina pomum*, which had been formerly in great part used by Bernardi in making lime, and which strongly reminds one of the similar mass that is observed in the grove of the Santagata, near Gesso. Having passed this small Miocene bed, the Rio was found encased in ancient scaly clays, identical with those of the Rio Centonara, which descends toward Ozzano, on the opposite slope of the same hill from which the Rio Cavaliera takes its origin, immediately under the church of Ciagnano. It is to be noted that about 200 meters east of Ciagnano, and in the direction of the course of the Rio della Cavaliera, the superb specimen of *C. Masseiana* was found in the same mass of scaly clays.

In the scaly clays of Rio della Cavaliera, as well as in those of the Rio Centonara, I have noted masses of yellowish-red and greenish clays, which recall certain jaspers and stannites of the Titonic and of the Cretaceous, besides aragonite, quantities of manganese-bearing concretions, masses of altered variolite, and traces of calcareous and siliceous serpentine (oficalce e ofisilice), with calcareous and jasper elements; which, in fact, suggest the Lower Cretaceous and Upper Jurassic of other regions. Upon the whole, as well from its position as from the relations of fossilization, even from the dimensions and form, there is good reason to maintain that there are close relations between the specimen of Cycadeoidea from the Rio della Cavaliera, collected in 1745, for which I propose the name of *C. Montiana*, and that of the Rio Centonara, found in 1890.

THE MESOZOIC OF PORTUGAL.

THE EARLIEST DICOTYLEDONS.

Prior to the year 1888 no dicotyledonous plants had been made known from any deposit older than the Cenomanian, with the sole exception of the *Populus primæva* of Heer from the Kome beds (Urgonian) of Greenland. The statement had therefore been frequently made, not only that the type of vegetation which now predominates throughout the world had its origin in the Middle Cretaceous, but that, in view of the great abundance of this type in the Cenomanian of Europe and of Greenland and in the Dakota group of the United States, supposed to be of Cenomanian age, the dicotyledonous flora had suddenly come into existence at that date.

It is a remarkable fact, though one paralleled many times in the history of science, that two persons independently of each other, and neither of whom was aware of the labors of the other, in regions separated by the entire breadth of the Atlantic Ocean, were simultaneously discovering the existence of this class of vegetable life at a much earlier age than that at which it had previously been found. Prof. William M.

Fontaine, of the University of Virginia, had at that date already been several years engaged in a careful study of what is now known as the Potomac formation, which he was then calling the Younger Mesozoic of Virginia; and, in view of the almost complete absence of other paleontological evidence, had been giving special attention to the fossil plants. He found these in many parts of this terrane, and although the great majority of them were ferns, cycads, and conifers, there were certain rare and obscure forms which he was unable to refer to any of these groups. They were for the most part broad expansions resembling fronds or leaves, with coarse reticulate nervation. It is due to his sagacity to say that he himself suspected that they might represent peculiar dicotyledonous leaves. Professor Fontaine wrote to me and described the forms which he had found. He subsequently came to Washington and showed me some of the specimens. I fully agreed with him that they represented dicotyledonous plants, and soon after he found localities on the James and Rappahannock rivers, and especially near Aquia Creek, in which these forms were much more abundant and better preserved. The question was definitively settled that they could not be, as was thought possible, ferns of the type of Dictyophyllum and Thaumatopteris, but must be in very truth dicotyledonous leaves. In his subsequent researches he made extensive collections of these forms and developed a rich flora in the Lower Cretaceous of Virginia.

So exceedingly important did I regard this discovery that I urged Professor Fontaine to publish a preliminary announcement of it in anticipation of his work on the flora of that formation, which did not appear until 1890, although it bears date 1889. He declined to do so, but gave me permission to mention the fact in a paper which I was then preparing.[1] It was then supposed that these beds were Jurassic, and at the close of a discussion of the origin of the dicotyledons I there remarked (pp. 302–303):

> It is to be hoped that we are at last approaching the beginning at least of a solution of this truly great problem of the origin of the dicotyledons. I have myself seen at least one slight, it may be, but very interesting sign of possible progress in this direction. Certain quite defective but very instructive specimens, collected in the Upper Jurassic of Virginia, by Prof. William M. Fontaine, and which he kindly brought to Washington for my inspection, certainly possess all the essential elements of dicotyledonous leaves, although at the same time bearing a certain recognizable stamp of the cryptogamic and gymnospermous vegetation that characterizes that earlier age. What is to be the final verdict of science upon these forms can not now be told, but it is to be hoped that the Mesozoic strata not only in Virginia, but in all parts of the world, may be diligently searched and the materials carefully studied, with a view to discovering these certainly merely "missing links" of a chain that can but have been once complete.

The manuscript of Professor Fontaine's Potomac or Younger Mesozoic Flora[2] was completed early in 1888 and submitted for publication,

[1] On Mesozoic Dicotyledons. Amer. Journ. Sci., 3d ser., Vol. XXVII, April, 1884, p. 292–303.
[2] Monographs of the U. S. Geol. Surv., Vol. XV, Washington, 1889.

But, as is well known, from one to two years is required to bring out a work of this magnitude, and I again endeavored to prevail upon him to publish a popular statement of the dicotyledonous flora which it describes. With his characteristic modesty he still declined to do so. He, however, not only permitted but requested me to perform this duty. I brought the matter to the attention of Major Powell, Director of the Survey, and Professor Marsh, president of the National Academy of Sciences, from both of whom I received a courteous invitation to present these results to the National Academy at its meeting at Washington in 1888. I did so, and the paper was published in August of that year.[1] Relative to the question here under consideration I there ventured the following statements (pp. 129–131):

It remains to consider the second question, as to the true significance of the dicotyledons. Their presence is supposed to indicate a later age than that denoted by the other groups of plants. It was long supposed that the upper Quader beds of Blankenburg contained the earliest remains of plants of this class, but they were at length found in the considerably older strata of Niederschoena in Saxony. Since then their occurrence in strata of about the same age in Bohemia and Moravia was made known, and it is the practice to treat the so-called Upper Cretaceous of Greenland, the Dakota group of Kansas and Nebraska, and the Raritan clays of New Jersey as homotaxially equivalent to these Continental deposits.

With but a single exception no dicotyledonous plants had been found lower than this horizon prior to the discovery of the Fredericksburg bed. This exception was the occurrence among the collections from Kome in Greenland, a deposit whose animal remains are said to fix its age as Urgonian, of a single dicotyledonous species, the *Populus primæva* of Heer, all the other plant remains from that deposit belonging to the lower types. Although this discovery has not been confirmed by subsequent research, and therefore remains subject to the doubt whether the collections may not have become mixed with those from higher beds made and sent at about the same time, still there is nothing antecedently improbable in it, and it may pass unquestioned. It does not, however, invalidate the general proposition that up to this time the Cenomanian has furnished the most ancient forms of dicotyledonous plants.

This can not now be said, and we have in the Potomac formation a still earlier date at which to fix the observed origin of the type of vegetable life which is now the predominant one upon the globe. What then does this dicotyledonous element in the Potomac flora prove as to the age of that formation? Can we argue from its analogy with other Cretaceous floras? In doing so great caution is required. As compared with these the Potomac flora is wholly anomalous in this respect. In all the others, with the sole exception already mentioned, instead of those plants coming in gradually, as they would be expected to do if the formation represented an age at which their development was inchoate, and instead of presenting rudimentary transition and archaic types of that subclass, as such early deposits would naturally do, we find them to be the prevailing, sometimes, as in the Dakota group, almost the only form of plant life, and we also find them fully developed, and even when most unlike our modern vegetation, still exhibiting all the characters of highly organized plants of their rank. In the Potomac formation, on the contrary, we find the dicotyledons behaving precisely as they ought to behave in a formation that represents an age close down to that at which this form of life first made its appearance in the geologic history of the globe. We find them to constitute the great rarities of the

[1] Evidence of the Fossil Plants as to the Age of the Potomac Formation. Amer. Journ. Sci., 3d ser., Vol. XXXVI, August, 1888, pp. 119–131.

flora, absent from many of the most productive beds, scarce at all places in comparison with the lower types of vegetation, strange and peculiar in character, so vague and ill-defined as in some cases to cause doubts as to whether they really belong to this group of plants, possessing features that recall the ferns, cycads, conifers, and even the monocotyledons, and containing comprehensive types prophetic of many of the now fully developed families of dicotyledons. They therefore form just such a homogeneous and undifferentiated group of plants, combining in a scarcely distinguishable way all the elements of the later dicotyledonous flora, as we should expect to find existing during the early history of this type of vegetation. They are therefore not to be regarded as anomalous, but as normal, and the anomaly, if any there be, exists in Cenomanian floras, where this type occurs in such a predominant and highly developed form.

In view of these facts I can not accept the conclusion that the dicotyledonous element of the Potomac flora argues a more recent age than that denoted by the other types. On the contrary, the immense difference between this and the Cenomanian floras clearly indicates that a vast period must have been required to produce so great a development.

On numerous occasions, dating as far back as 1878,[1] I have expressed the opinion that the dicotyledons could not have had their origin later than the Middle Jura, and it will not surprise me if the final verdict of science shall place the Potomac formation, at least the lower member, in which the plants occur, within that geologic system. While the remaining types point strongly in this direction, I do not regard the dicotyledons as at all negativing, but even more strongly suggesting this view.

Since that date the flora of the Potomac formation has been greatly increased by further discoveries, and the older beds from which Professor Fontaine obtained his specimens have been connected in an almost unbroken series with higher ones in Maryland, New Jersey, New York, and Massachusetts—the Albirupean, Raritan (Amboy Clays), and Island series, as well as with the Tuscaloosa formation of Mississippi and Alabama, in all of which the dicotyledonous element largely predominates, amounting to 330 species out of a flora of 707 species. I regard all this as belonging to the Lower Cretaceous in the sense in which I have used that term in this paper, viz, from the Wealden and Neocomian to and including the Gault and Albian of Old World nomenclature.

As already remarked, a similar series of investigations was being carried on in Europe simultaneously with the ones just recorded. Not long after I had had the correspondence with Professor Fontaine to which reference has been made I began to receive letters from the Marquis Saporta, drawing my attention to the existence of peculiar forms in the Lower Cretaceous of Portugal, some of which he was obliged to refer to the group he had established under the name Proangiosperms, and others of which, he was quite sure, represented true dicotyledons. I acquainted him with the results reached by Professor Fontaine, and in 1888, or the same year as the publication of my paper last quoted, he came forward with his first statement of this peculiar

[1] American Naturalist, Vol. XII, June, 1878, p. 378; November, 1878, p. 734. In a lecture delivered February 24, 1883, at the National Museum, on Plant Life of the Globe, Past and Present (see Science, Vol. I, May 4, 1883, p. 358). American Journal of Science, 3d ser., Vol. XXVII, April, 1884, p. 302. Proc. A. A. A. S., Vol. XXXIII, Philadelphia meeting, September, 1884, p. 497. Botanical Gazette, Vol. IX, Indianapolis, October and November, 1884, p. 174. Fifth Annual Rept. U. S. Geol. Surv., 1883-84, Washington, 1885, p. 449, diagram, pl. lviii, facing p. 452.

condition of things in Portugal.[1] In this paper are described, in a preliminary manner, certain collections made by M. Choffat from beds in Portugal of Lower Cretaceous age, but higher than those from which Heer, seven years earlier, had described an interesting flora, in which no dicotyledons appear. The present collections contained a number of undoubted dicotyledonous leaves. The age of the beds was probably about that of the Gault of England or Albian of France. With the exception of the American discoveries, this was therefore the lowest horizon from which such plants had been reported.

The following statement contained in this paper is directly in point (p. 1502):

> The only essential difference which distinguishes these beds from those with which Heer was acquainted consists in the constant presence in the former of a certain number of dicotyledons, a class of plants the date of whose introduction in Portugal is thus determined and circumscribed by the vertical space which separates the Urgonian from the Cenomanian. This supposed date is in fact entirely conformable to the observations made upon this same question in Central Europe, where the Wealden and even the Urgonian (Wernsdorf beds in the Carpathian mountains) are found to be devoid of dicotyledons, while the plants of this class are already numerous and varied in the Cenomanian of Bohemia, in that of Saxony (Niederschoena), and of Moravia (Moletein). In the present state of our knowledge and in view of the discoveries in Portugal it is therefore at the stage of the Almargem, that is to say, at the Aptian and Albian, more precisely at the Bellasian of the Portuguese,—Vraconnian of the Jura,—Upper Gault,—horizon of *Pterocera incerta* d'Orb., *Ostrea pseudo-africana* Choff., *Sphaerulites Verneuilli* Coq., *Sphenodiscus Uhligi* Choff., that it is necessary to place the moment at which the dicotyledons commenced to be introduced and to spread in Europe.

But soon after I learned from the Marquis that other collections from still older formations also contained dicotyledons, and in 1891 he published a second paper[2] calling attention to these earlier forms from the Urgonian of Cercal. This paper begins with the following significant statement:

> The appearance and first extension of the dicotyledonous angiosperms, long excluded from the terrestrial flora, of which they form at the present time the principal element, certainly constitute the most considerable event of which the annals of the vegetable kingdom have preserved any trace. How was this phenomenon produced, to what date should it be referred, and what were the characters of the most ancient plants of the new type? These are questions which it is natural to ask and which belong to the domain of those which paleontology has for its object to solve. Thus far, however, for want of proof, this science has not been able to answer them; and while the Urgonian flora of the Carpathians embraces no vestige of dicotyledons, those of the Cenomanian of Bohemia already include a rich series of them, coming without doubt within the range of still existing genera, or offering with these, in appearance at least, no well-marked contrast from the morphological point of view. The improbable idea of a sudden creation once rejected, it was necessary to have recourse to the hope of one day meeting, at stages anterior to the Cenomanian, with dicotyledons closer to their point of origin than those of the chalk

[1] Sur les Dicotylées prototypiques du système infra-crétacé du Portugal. Comptes rendus de l'Acad. Sci. de Paris, Tome CVI, 28 mai, 1888, pp. 1500-1504.

[2] Sur les plus anciennes Dicotylées européennes observées dans le gisement de Cercal, en Portugal. Comptes rendus, etc. Tome CXIII, 3 Août, 1891, pp. 249-253.

of Bohemia. Already the researches of the geological survey of Portugal, directed by M. Delgado, with the cooperation of M. P. Choffat, had enabled me to indicate at Buarcos dicotyledons probably of Albian age. More recently the flora of the Potomac in Virginia, published by M. Fontaine, has brought to light dicotyledons still nearer to the extreme base of the Cretaceous series. Prof. L. Ward, in a notice of these dicotyledons,[1] has not failed to set forth the synthetic characters and embryonic affinities of many of them, recognizing in such traits the indications of an evolution in process of accomplishment. It is indications of the same nature, even more accentuated, that I meet with among the angiosperms of the flora of Cercal, a Portuguese deposit inclosed between the fossiliferous Cenomanian and the Neo-Jurassic upon which it rests. The Commission des Travaux géologiques has succeeded in obtaining from this deposit a collection of plants, of which I shall here sum up the most salient characters.

In this paper he briefly discusses a few of the ancestral types (Protorhipis, Protolemna, Poacites, etc.), which will be more fully considered in the sequel.

It was evident from this that Saporta was monographing this flora, and the final report was awaited with much impatience. It arrived, as we shall see, late in the year which preceded his death.

In view of the special importance of the Mesozoic flora of Portugal, I have been to the trouble to prepare a somewhat complete history of the discovery in that field, which may be appropriately introduced in this place, in the course of which I have made careful comparisons with the similar conditions on this side of the Atlantic.

HISTORICAL NOTICE.

The earliest studies in the Mesozoic deposits of Portugal seem to have been made by Mr. Daniel Sharpe, who read a paper before the Geological Society of London on April 11, 1832, describing certain beds in the vicinity of Lisbon and Oporto, in the former of which were included strata referred by him to the Oolite. On the 9th and 23d of January, 1839, he presented a second paper, describing more fully the secondary formation in the vicinity of Lisbon.[2] On November 21, 1849, Mr. Sharpe read still a third paper, before the same society,[3] of a much more extended nature and devoted entirely to the secondary formation. In this paper is a full list of all the fossils known down to that date, carefully determined by Mr. John Morris. Included in these was a single fossil plant regarded by Mr. Morris as a variety of a species of the Yorkshire Oolite, called by Phillips *Cycadites gramineus*. It was found at Cape Mondego, and from this circumstance was given the varietal name *Mundæ*. Mr. Morris referred Phillips's plant to the genus Zamites, and called the Portuguese species *Z. gramineus*, var. *Mundæ*. Schimper recognized in it an Otozamites, and Heer afterwards changed the name to *O. angustifolius*. By the correct rules of nomenclature it should be called *Otozamites Mundæ*.

[1] Referring to the above-mentioned paper in the Am. Journ. Sci., 3d ser., Vol. XXXVI, August, 1888, pp. 119-131.

[2] Geol. Soc. London, Proc., Vol. I, p. 395; Vol. III, p. 31; Trans., 2d ser., Vol. VI, p. 115 ff.

[3] Quart. Jour. Geol. Soc., London, Vol. VI, pp. 135–201.

In 1858 Sr. Carlos Ribeiro published a series of elaborate papers on the Geology of Portugal,[1] treating chiefly of the Carboniferous; but in two of these[2] he considers the Lias and Oolite, mentioning the plant above referred to from Cape Mondego and four other species from this and other localities.

Meantime other collections were being made, and in 1880 M. Paul Choffat published a somewhat elaborate report on the Geology of the Jurassic of Portugal[3] in which the fossil plants were considered as far as available. The collections were sent by Choffat to Prof. Oswald Heer, and a preliminary report upon them was received in time to be inserted as an addendum. Heer's full report appeared a year later[4] and constitutes the first important contribution to the Mesozoic flora of Portugal. It also includes a large number of Tertiary plants. The Mesozoic horizons are here regarded as embracing, first, the Rhetic; second, the Jurassic, subdivided into Lias, Oolite or Dogger, and Upper Jurassic or Malm; and third, the Cretaceous, which was largely compared with the Wealden of other parts of Europe. Heer found in these collections 5 Rhetic, 18 Jurassic, and 23 Cretaceous forms. The Cretaceous plants consisted chiefly of ferns, cycads, and conifers, but two of them were referred to the monocotyledons. No traces of dicotyledons were discovered.

M. Choffat continued his investigations, and after Heer's death sent the plant impressions to the Marquis Saporta at Aix. The latter was greatly interested in them and published three preliminary reports, two of which have already been mentioned; the other[5] relates to the Jurassic. Some of the horizons in the Cretaceous were the same as those containing the plants described by Heer, while others were considerably higher. The full report upon these interesting collections has been waited for with great impatience, especially by American geologists familiar with our Potomac formation, in which the case is so nearly paralleled. In fact I was so desirous of learning more in regard to them that by previous arrangement with the Marquis, and at his urgent request, I paid a visit to the veteran paleobotanist at Aix, in the south of France, and through his extreme courtesy was not only permitted to examine these collections, but enjoyed the great favor of discussing with him a large number of most interesting questions to which they gave rise. It was then that I learned that the final report was already in press and would soon appear, and proof sheets both of the text and plates were already in the possession of the author, so that it was possible

[1] Mem. Acad. Real. Sci. de Lisboa, New Ser. Vol. II.

[2] Mina de Carvão de Pedra do Cabo Mondego, and do Districto de Leiria, op. cit., Pt. II, Third and Fourth Memoirs (these memoirs are separately paged).

[3] Étude stratigraphique et paléontologique des terrains Jurrassiques du Portugal. Première livraison. Le Lias et le Dogger au Nord du Tage. Section des travaux géologiques du Portugal, Lisbonne, 1880.

[4] Contributions à la flore fossile du Portugal par le Dr. Oswald Heer. Section des travaux géologiques du Portugal, Lisbonne, 1881.

[5] Comptes rendus Acad. Sci. de Paris, Vol. CXI, December 1, 1890, pp. 812–815.

to examine the work in immediate connection with the specimens. This work[1] appeared before the end of 1894, scarcely a month before his death, which occurred on January 26, 1895, so that he was unable to distribute it, as I know he intended to do, among his correspondents; but copies were sent out by the geological survey of Portugal and a few are in the hands of American geologists. It may as well be stated here that although a large and voluminous report, containing 288 quarto pages and 39 plates, it still comes far short of covering the material that was then in the author's hands. The collections were sent to him in installments almost every year and were still arriving, but it was necessary to fix some limit, and the work was closed at a certain date and sent to press, since which time other collections had been received, upon which he was at the time actively engaged, and these were also carefully examined on that occasion at the Château of Fonscolombe, the country residence of the Marquis, 16 kilometers north of Aix. These were to be reported upon in a subsequent memoir. The remarkable parallelism between the plant-bearing deposits of the west coast of Portugal and those of the eastern part of the United States, and especially between the Lower Cretaceous of Portugal and our Potomac formation, gives an especial interest to this memoir.

THE JURASSIC FLORA.

In America there is a decided time hiatus between the lowest Potomac beds and the next plant-bearing horizon below, which is now regarded as belonging to the extreme Upper Triassic and as about the equivalent of the Keuper deposits of Lunz in Austria.[2] In Portugal, on the contrary, there appear to be no plant-bearing horizons in the Trias proper, but in the Jurassic a considerable number of such deposits have been found. M. Choffat, who prepared the geological part of this memoir, follows as closely as possible the nomenclature of the French geologists, and it is found that plant-bearing horizons occur in the Infralias, part of which may be as low as the Rhetic, and some of which is referred to the Sinemurian; in the Lias; in several of the properly Oolitic beds (Toarcian, Bajocian, Callovian, etc.); in several members of the Corallian; and especially in still higher beds classed as Neo-Jurassic, which are mainly correlated with the Kimmeridgian, but may extend into the Portlandian. The Jurassic deposits of Portugal consist of sandstones and limestones, the former predominating below; and while all of them may not be of marine origin, so large a part is fossiliferous that by the aid of the careful stratigraphical investigations of the Portuguese geologists it has been possible to fix the position of the plant beds with relation to those holding animal remains, a fact which is of the utmost importance in determining the validity of the evidence of

[1] Flore fossile du Portugal. Nouvelles contributions à la flore Mésozoique par le Marquis Saporta. Accompagnées d'une notice stratigraphique par Paul Choffat. (Avec 40 planches.) Direction des travaux géologiques du Portugal, Lisbonne, 1894.

[2] See Bull. Geol. Soc. Am., Vol. III, 1891, p. 31.

fossil plants in such countries as America, where for the most part no such guide exists.

The Jurassic flora of Portugal, as embraced in the present memoir and in that of Heer already mentioned, consists of 126 species, as follows:

List of the Jurassic plants of Portugal, with their distribution in that country.

Species.	Jurassic.					Cretaceous.			
	Infralias.	Lias.	Oolite.	Corallian.	Neo-Jurassic.	Valanginian.	Urgonian.	Aptian.	Albian.
Abietites fructifolius Sap.					+				
Adiantum dispersum Sap.					+				
distractum Sap					+				
longiquum Sap					+				
Alethopteris Choffati Sap.					+				
? discerpta Sap					+				
Baiera dilatata Heer	+								
Brachyphyllum Delgadonum Heer			+						
lusitanicum Sap				+					
majusculum Sap					+				
microcladum Sap					+				
micromorum Heer				+					
Cheirolepis Münsteri Schenk	+								
Chondrites bollensis Heer			+	+					
Chrysodiopteris marchantiæformis Sap					+				
Cladophlebis angulata Sap					+				
Browniana (Dunk.) Seward					+	+			
microlepsina Sap					+				
micromorpha Sap					+				
minor Sap					+	+			
multipartita Sap					+				
obtusiloba Sap					+				+
parvula Sap					+				
sinuatiloba Sap					+				
undulatiformis Sap					+				
Clathropteris sp. Sap	+								
Comptoniopteris dubia Sap					+				
incisa Sap					+				
sinnata Sap					+				
Cylindrites curvulus Heer			+		?				
lusitanicus Heer			+						
sp. Heer		+							
Equisetum deperditum Sap					+				
lusitanicum Heer				+					
pseudo-hœrense Sap	+								
striatulum Sap	+								
tenue Sap	+								
Granularia repanda Heer				+					
Gutbiera angustiloba Presl	+								
Hymenophyllites ambiguus Sap					+				
crenilobus Sap					+				
gracilis Sap					+				
tenellinervis Sap					+				
Microdictyon parvulum Sap					+				
Neuropteridium lacerum Sap					+				
venulosum Sap					+				
Onychiopsis Mantelli (Brongn.) Seward					+	+	+	+	+
Otozamites Mundæ Morr. sp				+					
Ribeiroanus Heer				+					
Terquemi Sap?	+								

List of the Jurassic plants of Portugal, with their distribution in that country—Continued.

Species.	Jurassic.					Cretaceous.			
	Infrahas.	Lias.	Oolite.	Corallian.	Neo-Jurassic.	Valanginian.	Urgonian.	Aptian.	Albian.
Pagiophyllum cirinicum Sap	---	---	---	+	+	---	---	---	---
Combanum Heer	+	---	+	---	---	---	---	---	---
Heerianum Sap	---	---	---	---	+	+	---	---	---
liasinum Sap	+	+	---	---	---	---	---	---	---
minus Sap	---	---	---	---	+	---	---	---	---
peregrinum (L. & H.) Heer	+	---	---	---	---	---	---	---	---
Palæocyparis flexuosa Sap	---	---	---	---	+	+	---	---	---
lusitanica Sap	---	---	---	---	+	---	---	---	---
vetustior Sap	+	---	---	---	---	---	---	---	---
Palissya Braunii Endl	+	---	---	---	---	---	---	---	---
lusitanica Sap	+	---	---	---	---	---	---	---	---
Pecopteris acutiloba Sap	---	---	---	---	+	---	---	---	---
obliquinervis Sap	---	---	---	---	+	---	---	---	---
stricta Sap	---	---	---	---	+	---	---	---	---
Poacites angustiformis Sap	+	---	---	---	---	---	---	---	---
antiquior Sap	---	---	---	---	+	---	---	---	---
binervius Sap	---	---	---	---	+	---	---	---	---
cyperaceus Sap	+	---	---	---	---	---	---	---	---
exiguus Sap	---	---	---	---	+	---	---	---	---
primordialis Sap	---	---	---	---	+	---	---	---	---
striatifolius Sap	---	---	---	---	+	+	---	---	---
Podozamites lacerus Sap	---	---	---	---	+	---	---	---	---
minutus Sap	---	---	---	---	+	---	---	---	---
? obtruncatus Sap	+	---	---	---	---	---	---	---	---
sp. Sap	---	---	---	---	+	---	---	---	---
Pteridoleimma lacerum Sap	---	---	---	---	+	---	---	---	---
residonum Sap	---	---	---	---	+	---	---	---	---
Rhizocaulon vetus Sap	---	---	---	---	+	+	---	---	---
Schizoneura hœrensis Heer	+	---	---	---	---	---	---	---	---
Scleropteris acutidens Sap	---	---	---	---	+	---	---	---	---
densior Sap	---	---	---	---	+	---	---	---	---
Pomelii Sap	---	---	---	---	+	---	---	---	---
proxima Sap	---	---	---	---	+	---	---	---	---
sinuata Sap	---	---	---	---	+	---	---	---	---
subdentata Sap	---	---	---	---	+	---	---	---	---
tenuisecta Sap	---	---	---	---	+	---	---	---	---
Zeilleri Sap	---	---	---	---	+	---	---	---	---
Sphenolepidium Choffati Sap	---	---	---	---	+	---	---	---	---
Sphenopteris acutidens Sap	---	---	---	---	+	---	+	---	---
adjuncta Sap	---	---	---	---	+	---	---	---	---
anticolobula Sap	---	---	---	---	+	---	---	---	---
breviloba Sap	---	---	---	---	+	---	---	---	---
deflexa Sap	---	---	---	---	+	---	---	---	---
Delgadoi Sap	---	---	---	---	+	---	---	---	---
densa Sap	---	---	---	---	+	---	---	---	---
dissectifolia Sap	---	---	---	---	+	+	---	---	---
fracta Sap	---	---	---	---	+	---	---	---	---
marginata Sap	---	---	---	---	+	---	---	---	---
microclada Sap	---	---	---	---	+	---	---	---	---
microlepisina Sap	---	---	---	---	+	---	---	---	---
minima Sap	---	---	---	---	+	---	---	---	---
odontoceras Sap	---	---	---	---	+	---	---	---	---
ovatiloba Sap	---	---	---	---	+	---	---	---	---
pallida Sap	---	---	---	---	+	---	---	---	---
palmifida Sap	---	---	---	---	+	---	---	---	---
pedicollata Sap	---	---	---	---	+	---	---	---	---
proxima Sap	---	---	---	---	+	---	---	---	---

List of the Jurassic plants of Portugal, with their distribution in that country—Continued.

Species.	Jurassic.					Cretaceous.			
	Infralias.	Lias.	Oolite.	Corallian.	Neo-Jurassic.	Valanginian.	Urgonian.	Aptian.	Albian.
Sphenopteris subtilinervis Sap	---	---	---	---	+	+	---	---	---
tenelliloba Sap	---	---	---	---	+	---	---	---	---
tenellisecta Sap	---	---	---	---	+	---	---	---	---
thinnfeldiæformis Sap	---	---	---	---	+	---	---	---	---
trapezoidea Sap	---	---	---	---	+	---	---	---	---
tricholoba Sap	---	---	---	---	+	---	---	---	---
trifida Sap	---	---	---	---	+	---	---	---	---
Stachypteris litophylla Pom	---	---	---	---	+	---	---	---	---
minuta Sap	---	---	---	---	+	+	---	---	---
Taonurus procerus Heer	---	---	+	---	---	---	---	---	---
scoparius Heer	---	---	+	---	---	---	---	---	---
Thuyites Choffati Heer	---	---	+	---	---	---	---	---	---
leptocladus Sap	---	---	---	---	+	---	---	---	---
pulchelliformis Sap	---	---	---	---	+	+	---	+	---
Thyrsopteris minuta Heer	---	---	---	+	---	---	---	---	---
Voltzia pachyphylla (Zigno) Schimp	+	---	---	---	---	---	---	---	---
recubariensis (Mass.) Schenk	+	---	---	---	---	---	---	---	---
Widdringtonites debilis Sap	---	---	---	---	+	+	---	---	---
Yuccites fimbriatus Sap	+	---	---	---	---	---	---	---	---

As will be seen from this table this flora embraces 21 species from the Infralias, 2 from the Lias, 8 from the Oolite, 9 from the Corallian, and 91 from the Neo-Jurassic, which about corresponds to the Kimmeridgian of England, with 5 species occurring in two of these horizons. The table also shows that no less than 14 species pass up into the Cretaceous beds. Most of these are cases in which the range is only from the Neo-Jurassic to the Valanginian, or from the uppermost Jurassic to the lowermost Cretaceous, but a few reach the Urgonian, Aptian, or even the Albian, while the widely distributed and polymorphous *Onychiopsis* (*Sphenopteris*) *Mantelli* occurs at all these horizons as well as in the Upper Jurassic beds. These species will be more specially considered in connection with the Cretaceous.

As regards botanical affinity this flora is subdivided into 7 algæ, 6 equiseta, 71 ferns, 7 cycads, 26 conifers, 8 monocotyledons, and 1 species of Yuccites referable to the group Proangiosperms. Of the ferns, which so largely predominate, 26 species belong to the genus Sphenopteris, 10 to Cladophlebis, 8 to Scleropteris, and 4 to Hymenophyllites. Of the conifers, which come next in importance, 6 belong to Pagiophyllum, 5 to Brachyphyllum, and 3 to Thuyites. The cycads belong to the two genera Podozamites and Otozamites. Seven of the monocotyledons consist of small blades and culms of supposed grasses, grouped under the genus Poacites.

A comparison of this Jurassic flora with that of the American Trias reveals the fact that while only 3 species, *Cheirolepis Münsteri*, *Pagio-*

phyllum peregrinum, and *Palissya Braunii*, are common to the two, there are 14 genera that occur in both. In the number of species the two floras as now known are almost equal, that of the American Trias numbering 119, while that of the Portuguese Jurassic numbers 126. It is therefore important to note in what proportions these 14 genera occur in the two floras:

Genera common to the American Trias and the Jurassic of Portugal.

Genera.	Number of species.	
	American Trias.	Jurassic of Portugal.
Baiera	3	1
Brachyphyllum	1?	5
Cheirolepis	2	1
Chondrites	3	1
Cladophlebis	7	10
Clathropteris	2	1
Equisetum	6	5
Otozamites	4	3
Pagiophyllum	6	6
Palissya	3	2
Pecopteris	1	3
Podozamites	2	4
Schizoneura	5	1
Voltzia	1	2

When we consider that the two horizons do not at all overlap and that more than three-fourths of the Portuguese plants come from the uppermost members of the Jurassic, it is not to be expected that the correspondence will be very close; and accordingly we not only miss in the Portuguese flora some of the largest American genera, such as Acrostichites, Ctenophyllum, and Pterophyllum, but also some of the most striking and abundant forms, such as Macrotæniopteris, while on the other hand no monocotyledons occur in the American Trias so far as known, and the two largest genera of ferns in the Portuguese Jurassic, Sphenopteris and Scleropteris, are entirely wanting in the American Trias.

The remarkable feature of this Upper Jurassic flora of Portugal is the large number of ferns that are closely related to those of the Lower Cretaceous of the United States, and this alone would justify the above discussion of the Jurassic flora. The comparisons which Saporta makes are confined almost exclusively to the two genera, Sphenopteris and Cladophlebis, although he does note a close resemblance between his *Scleropteris sinuata* and Fontaine's *S. virginica*. In the genus Cladophlebis he compares his *C. angulata* with Fontaine's *C. parva;* his *C. sinuatiloba* with *C. crenata*, and also with *Aspidium fredericksburgense* Font.; his *C. obtusiloba* with *C. constricta*, and also with *Pecopteris strictinervis* Font. With this last species he also compares his *Pecopteris strieta*, showing that he, too, has difficulty in distinguishing

Pecopteris from Cladophlebis; and undoubtedly the movement which Mr. Seward has inaugurated in the direction of eliminating the genus Pecopteris entirely from Post-Paleozoic horizons will now go on until it becomes complete and the genus Pecopteris is restricted, as it should be, to the Paleozoic. The number of species of Sphenopteris compared with American forms is still greater. For example, he compares his *S. palmifida* with two of Fontaine's species of Acrostichopteris, *A. densifolia* and *A. longipennis*. His *Sphenopteris ovatiloba* he compares with Fontaine's *S. latiloba;* but most of his comparisons of Sphenopteris are with species that Fontaine refers to Thyrsopteris; for example, *Sphenopteris Delgadoi* is compared with *Thyrsopteris Meekiana* and *T. elliptica*. He also compares his *S. tenelliloba* with *T. elliptica* and with *T. densifolia;* and again his *S. marginata* is compared with Fontaine's two species, *T. insignis* and *T. pachyraehis*. These comparisons and some others that might be mentioned are sufficient to indicate the close affinities of these Mesozoic genera of ferns and the great difficulty that even the best authorities have in drawing clear lines of demarkation among them. It is probable that the genus Thyrsopteris, which is a rare type in the living flora, does not actually occur in the fossil state, and it will be better in the end to refer all these forms to extinct genera, such as Cladophlebis, Sphenopteris, Onychiopsis, Ruffordia, etc.

But the special interest which these comparisons have in this place is the intimate bond which they furnish between the late Jurassic of Portugal (supposed to correspond closely with the Kimmeridge clays of England, but perhaps running up into the Portland beds, and thus closely approaching the Purbeck, which has been treated in this paper as a part of the Wealden) and the oldest Cretaceous of America, which some geologists in this country make to extend some distance into the Jurassic, but which is here treated as a Cretaceous deposit.

THE CRETACEOUS FLORA.

The Cretaceous flora of Portugal has, of course, a much greater interest for the student of American paleobotany than the Jurassic flora which has just been considered; first, because, as now known, it is considerably larger, numbering 204 species, but chiefly because we have in America a large number of plant-bearing deposits that correspond so closely with those of Portugal that a comparison may be legitimately made, and furnishes valuable results. It is true that our American Lower Cretaceous flora has been now so extensively worked that it has assumed relatively large proportions, numbering at the present date over 800 different species. The Potomac formation alone furnishes no less than 737 species. The interest is still further heightened by the fact that in the Lower Cretaceous of both Portugal and America the plant-bearing beds occur at a number of distinct horizons, which may not without profit be directly compared in the two countries. For example, the Potomac formation now furnishes at least five distinct hori-

zons from which fossil plants have been obtained, the lowest being the James River series, which may extend as low as the top of the Jurassic. The next higher is the Rappahannock series, so well known at Fredericksburg, Va., and other points on the Rappahannock and Potomac rivers. The third is the Mount Vernon clays which directly overlie the last named and have furnished a distinct flora. The fourth is the Aquia Creek series which unconformably overlies the last, in some places at least. The fifth is undoubtedly much higher, and there appears to be a considerable thickness of nonfossiliferous deposits intervening between the last named and those plant-bearing beds that have been discovered on the eastern side of the District of Columbia and at other points near Washington, on the Severn River, and on the eastern shore of the Chesapeake Bay, which have furnished a flora substantially identical with that of the Amboy Clays on the Raritan River, and not widely differing from that of Staten Island, Long Island, and Marthas Vineyard, which I have called the Island series, nor from that of the Tuscaloosa formation of Alabama.

The Lower Cretaceous of Portugal is subdivided into a very similar series of plant-bearing deposits. One locality, Valle-de-Bronco, is referred by Choffat to the Infravalanginian, which is at the very base of the Neocomian, and corresponds well with our James River series. An important plant-bearing locality between Matta and Valle-de-Lobos, is regarded as Valanginian or Neocomian, as is also the series in the vicinity of Torres-Vedras, viz, at S. Sebastião, Quinta-da-Fonte-Nova, Forca, etc. This horizon may be compared with the Rappahannock series of the Potomac formation. Near Cercal and Zambujeiro a large flora has been obtained. The plants are of rather ancient types, but denote a horizon considerably higher than the one last mentioned. Saporta refers them to the Urgonian, and M. Choffat does not decidedly object to this, but says that the stratigraphy, so far as he can judge, would indicate a somewhat later age. This horizon may be nearly the same as that of the Mount Vernon series of the Potomac formation. The beds of Almargem, which have furnished many species, chiefly determined by Heer, overlie the recognized Urgonian and probably belong to the next one, called by the French geologists the Aptian. Certain other beds, as at Caixaria and Caranguejeira, are less definitely fixed geologically, but probably belong to about the same horizon. The Aptian of the French geologists lies between the Urgonian below and the Albian above, and corresponds in the main with the Lower Greensand of England. It may be compared with the Aquia Creek series of the Potomac formation, which has yielded a large number of fossil plants, including such well-marked dicotyledons as Celastrophyllum and Sapindophyllum.

Above these beds there is an abundant plant locality at Buarcos, which is classed as Albian, and still higher others at Nazareth, Alcanede, and Monsanto, also regarded as Albian, but as belonging to that

uppermost member called Vraconnian. The Albian corresponds in a general way with the Gault and is the uppermost section of the Lower Cretaceous, the overlying beds being Cenomanian, which is the lowest subdivision of the Upper Cretaceous. These Albian plant-bearing beds may be roughly compared with what has been called in America the Amboy Clays, but which has recently been more correctly named by Prof. William B. Clark the Raritan formation. In America, as in Portugal, this deposit may also be divided into two parts, a lower and an upper, the former consisting of the beds along the Raritan, which themselves have a considerable thickness and show marked changes in the flora, while to the latter belong the deposits on Staten Island, Long Island, Marthas Vineyard, the Island series, which have yielded large collections chiefly from indurated nodules formed in red clay. If the Buarcos bed is correlated with the Raritan, the Vraconnian may correspond to the Island series.

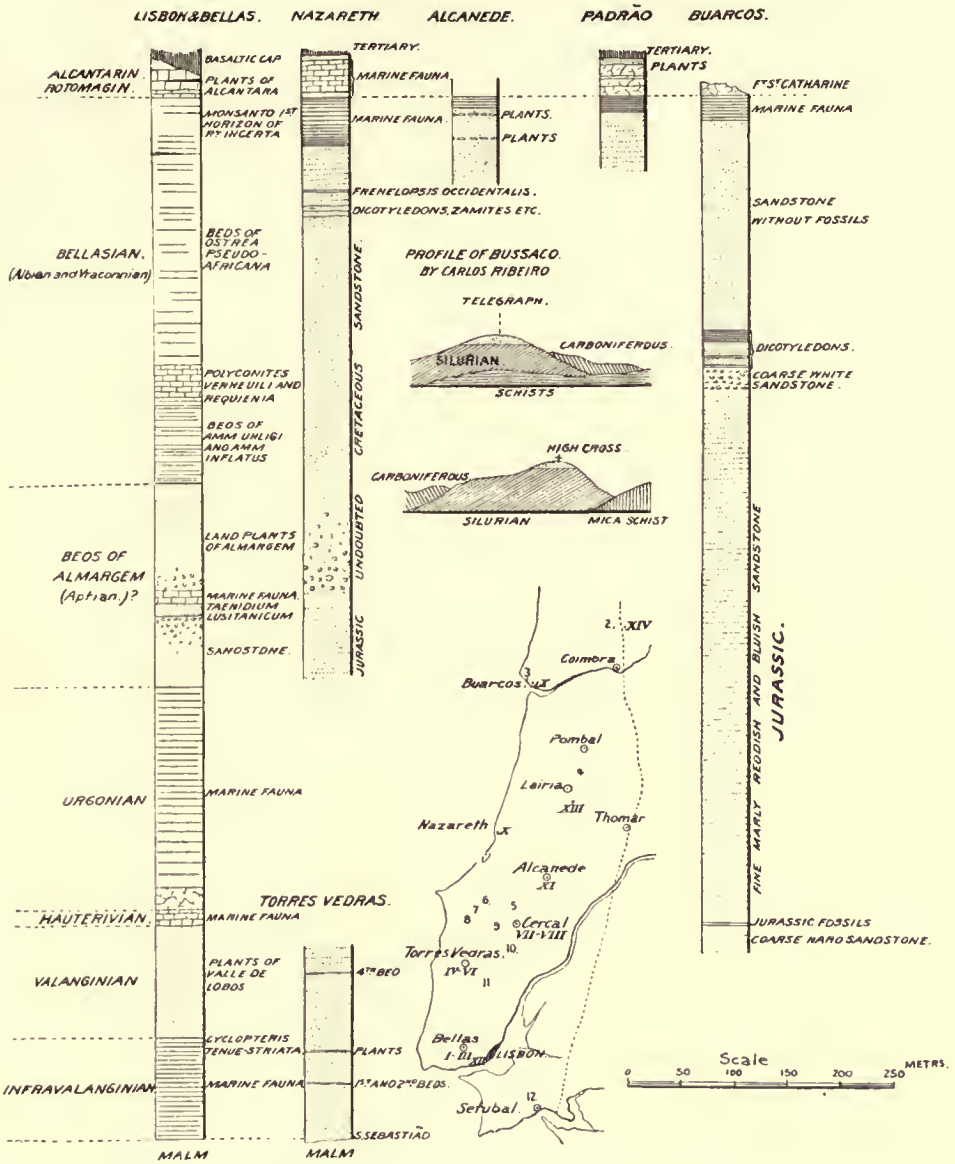
Finally, in the valley of Alcantara, at Padrão, Pombal, and Villa-Verde-de-Tentugal, there are plant-bearing beds belonging to the Cenomanian. It is possible that these latter may not be higher than those of Long Island and Gay Head.

In describing the lithological character of the strata in the vicinity of Torres-Vedras, M. Choffat says:

> The sandstones of Torres are in general incoherent; they contain numerous worn quartzites either in grains or pebbles, sometimes attaining the size of the fist and giving place to conglomerates. Some beds are fine and argillaceous; there are even clay masses and also beds of siliceous cement forming true quartzites. The color of the whole is a yellowish-white, sometimes reddish; the clays are sometimes dark gray, but they are in too small quantity to influence the general aspect, the whitish color of which is chiefly due to the presence of kaolin.

As regards the plant beds he almost always describes them as consisting of clay lenses ("lentilles d'argile"), and in much of his general description he might have been treating of the Rappahannock series of Virginia, so similar are these practically equivalent beds on opposite sides of the Atlantic.

I had had some curiosity to know how the fossil plants from the Portuguese beds occurred. Most of the fossil plants known are broken out of hard rock, the leaf impressions forming natural planes of cleavage; these may be sandstones or indurated clays, rarely limestones; but in the Potomac formation the case is entirely different. In all beds below the Island series the plants occur in clay, which is either laminated or regularly stratified between the sands, or else it occurs in lenses and pockets, the latter being the prevailing form in the older beds (James River and Rappahannock series), and the former being the regular mode of occurrence in all the Newer Potomac deposits (Albirupean, Raritan clays, etc.). In the Island series, however, the plants mostly occur in nodules, which are more or less completely lithified, but are formed within the clay after the manner of concretions by the action of iron and other minerals. I was therefore greatly interested to examine the



COLUMNAR AND PROFILE SECTIONS OF THE CRETACEOUS OF PORTUGAL.

matrix in which the Portuguese fossil plants occur. It evidently corresponds very closely with that of the great majority of the Potomac deposits. The plants occur in the clays, which are more or less soft and even plastic when first exposed, but harden on drying. In some of the Potomac beds the vegetable matter of the leaves remains as a thin, black film covering the clay, which, being damp when first exposed to the light, almost immediately cracks and crumples on drying, and is thus more or less completely lost. But in most cases the vegetable matter is reduced by compression and other influences almost to a mere stain, often of a brownish color, upon which the fine nerves are distinctly visible. This last seems to be the character of the preservation of these impressions in the Portuguese beds, and the similarity in the nature of the matrix is very marked.

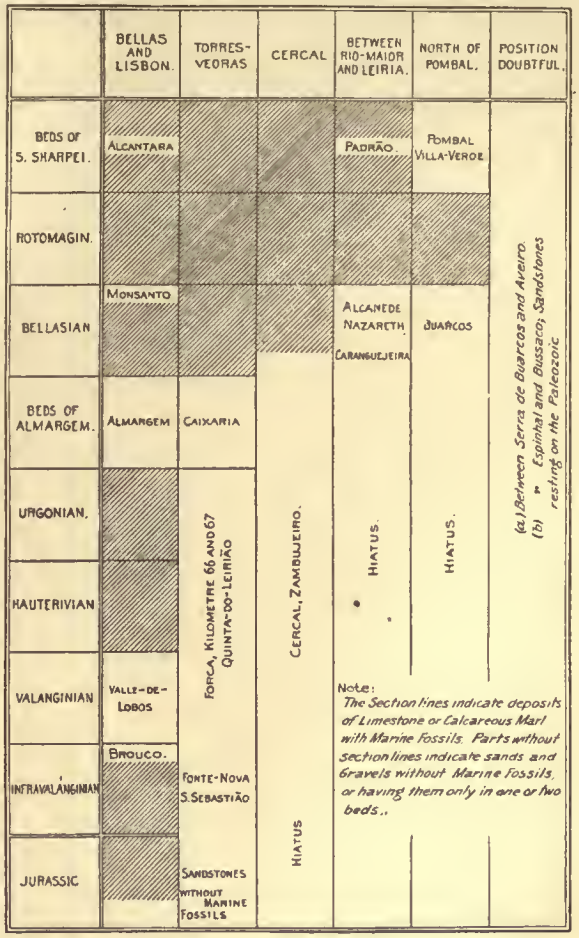


FIG. 69.—Correlation table of the Mesozoic deposits of Portugal. From Paul Choffat, 1894.

I give herewith (Pl. CV) the diagram of the Cretaceous plant-bearing beds of Portugal prepared by M. Choffat and published in the joint memoir of Saporta and himself. It embraces a small sketch map of the locality and profiles. I also give (Fig. 69) his diagram showing the correlation of these several beds.

Properly to illustrate the character of the Lower Cretaceous flora of Portugal I have prepared three tables of distribution.

The first embraces the entire flora of 204 species and shows their distribution in Portugal alone, but throughout not only all the Lower Cretaceous beds, but also the Jurassic below and the Cenomanian above.

The second contains only the 11 species that occur in the Lower Cretaceous of America. None of them are peculiarly American species, but nearly all have a wide distribution over the world. Their complete lateral and vertical range is given.

The third table embraces 12 of the new species of Saporta which he compares with American species, or with species occurring in America, with the full distribution not only of the Portuguese forms, but of the plants with which they are compared.

List of the Lower Cretaceous plants of Portugal with their geological distribution in that country.

Species.	Mesozoic.						
	Cretaceous.						
	Lower Cretaceous.						
	Neocomian.	Urgonian.	Aptian.	Albian.	Vraconnian.	Cenomanian.	Jurassic
Abietites acicularis Sap	+						
Adiantum aneimiæfolium Sap	+						
dilaceratum Sap				+			
eximium Sap				+			
expansum Sap				+			
subtilinervium Sap	+						
tenellum Sap				+			
Adoxa præatavia Sap				+			
Alismites primigenius Sap	+						
Aneimidium lobulatum Sap		+					
minutulum Sap		+					
tenerum Sap		+					
Aralia calomorpha Sap				+			
proxima Sap				+			
Aristolochia Daveauana Sap				+			
vetustior Sap				+			
Baiera cretosa Schenk				+			
Bambusium latifolium Heer	+		?				
Blyttia infracretacea Sap		+					
Brachyphyllum confusum Sap			+				
corallinum Heer	+					+	
obesiforme Sap				+			
obesiforme elongatum Sap				+			
obesum Heer	+	+	+		+		
Braseniopsis vennlosa Sap				+			
villarsioides Sap				+			
Carpites burmanniæformis Sap		+	?				
granulatus Sap					+		
plicicostatus Sap		+					
Cauliuites atavinus Heer	+		+				
fimbriatus Sap	+						
Cedrelospermites vennlosus Sap	+						
Changarniera dubia Sap	+						
Choirolepis Choffati Sap	+						
Choffatia Francheti Sap		+					
Cissites obtusilobus Sap				+			
sinuosus Sap				+			
Cladophlebis argutidens Sap	+						
Browniana (Dunk.) Seward	+						+
confusior Sap				+			
derelicta Sap	+						
Dunkeri (Schimp.) Soward	+	+	+	+			

List of the Lower Cretaceous plants of Portugal with their geological distribution in that country—Continued.

Species.	Mesozoic.						
	Cretaceous.						
	Lower Cretaceous.						
	Neocomian.	Urgonian.	Aptian.	Albian.	Vraconnian.	Cenomanian.	Jurassic.
Cladophlebis fissipennis Sap.	+						
Limai Sap.				+			
minor Sap.	+						+
minutissima Sap.	+						
obtusiloba Sap.				+			+
sinuatilobula Sap.	+	+					
subcycadina Sap.	+						
Comptoniopteris cercalina Sap.		+					
Ctenidium dentatum Heer.			+				
integerrimum Heer.			+			+	
Ctenopteris ultima Sap.	+						
Cussonia ? lacerata Sap.				+			
Cycadites pygmæus Sap.				+			
tenuisectus Sap.				+			
Cyclopitys Delgadoi Sap.	+						
Cyclopteris tenuestriata Heer.	+						
Czekanowskia nervosa Heer.			+			+	
Delgadopsis rhizostigma Sap.		+					
Dicotylophyllum cerciforme Sap.		+					
corrugatum Sap.		+					
hederaceum Sap.		+					
lacerum Sap.		+					
Dictyopteris anomala Sap.	+						
infracretacica Sap.	+						
tenella Sap.	+						
Eolirion lusitanicum Sap.				+			
Equisetites Burchardti Dunk.	+						
Equisetum, sp. Sap.		+					
Eucalyptus angusta Sap.					+		
Choffati Sap.					+		
proto-Geinitzi Sap.					+		
Frenelopsis leptoclada Sap.	+		+				
occidentalis Heer.	+	+	?	+	+	+	
Glossozamites brevior Sap.	+						
dilaceratus Sap.	+						
modestior Sap.	+						
Isoetes Choffati Sap.		+					
Jungermannites vetustior Sap.		+					
Laccopteris pulchella Heer.			+				
Laurus attenuata Sap.					+		
notandia Sap.					+		
palæocretacea Sap.					+		
Leguminosites infracretacicus Sap.					+		
Lonchopteris lusitanica Sap.	+						
Lycopodites Francheti Sap.		+					
gracillimus Sap.		+					
Limai Sap.		+					
Magnolia Delgadoi Sap.				+			
Marattia minor Sap.	+						
Matonidium Gœpperti (Ett.) Schenk.	+		+				
Menispermites cercidifolius Sap.				+			
Microlepia pluripartita Sap.	+						
Myrica lacera Sap.					+		
revisenda Sap.					+		

List of the Lower Cretaceous plants of Portugal with their geological distribution in that country—Continued.

Species.	Mesozoic.						
	Cretaceous.						
	Lower Cretaceous.						
	Neocomian.	Urgonian.	Aptian.	Albian.	Vraconnian.	Cenomanian.	Jurassic.
Myrsinophyllum revisendum Sap.	....	....	....	+	....	....	....
venulosum Sap.	....	....	....	....	+	....	....
Neuropteridium spinulosum Sap.	+	....	....	....	....	....	....
torresianum Sap.	+	....	....	....	....	....	....
Oleandridium tenerum Sap.	+	....	....	....	....	....	....
Onychiopsis Mantelli (Brongn.) Seward	+	+	+	+	....	....	+
Osmunda retinenda Sap.	+	....	....	....	....	....	....
Pagiophyllum Heerianum Sap.	+	....	....	....	....	....	+
Palæocyparis flexuosa Sap.	+	....	....	....	....	....	+
obscura Sap.	....	....	....	+	....	....	....
Palæolepis bicornuta Sap.	....	....	....	+	....	....	....
emarginata Sap.	....	....	....	+	....	....	....
Pecopteris Choffatiana Heer.	+	....	....	....	....	....	....
dilacerata Sap.	+	....	....	....	....	....	....
dispersa Sap.	....	....	....	+	....	....	....
minutula Sap.	....	....	....	+	....	....	....
Peucedanites primordialis Sap.	....	....	....	+	....	....	....
Phlebomeris? falciformis Sap.	+	....	....	+	....	....	....
spectanda Sap.	....	....	....	+	....	....	....
Wilkommi Sap.	....	....	....	+	....	....	....
Phyllites inflexinervis Sap.	....	....	....	....	+	....	....
problematicus Sap.	+	....	....	....	....	....	....
triplinervis Sap.	....	....	....	....	+	....	....
Pinites cyclopterus Sap.	....	....	....	+	....	....	....
Poacites acicularis Sap.	....	+	....	....	....	....	....
cercalinus Sap.	....	+	....	....	....	....	....
gemellinervis Sap.	+	....	....	....	....	....	....
lævis Sap.	....	....	....	+	....	....	....
paucinervis Sap.	+	....	....	....	....	....	....
plurinervius Sap.	....	....	+	....	....	....	....
plurinervulosus Sap.	....	+	....	....	....	....	....
striatifolius Sap.	+	....	....	....	....	....	+
tenellus Sap.	+	....	....	....	....	....	....
Podozamites? acutus Sap.	+	+	....	....	....	....	....
Podozamites ellipsoideus Sap.	+	....	....	+	....	....	....
gracilior Sap.	....	....	....	+	....	....	....
Henriquesi Sap.	....	....	....	+	....	....	....
linearis Sap.	+	....	....	....	....	....	....
modestior Sap.	....	....	....	+	....	....	....
oviformis Sap.	+	....	....	....	....	....	....
Protophyllum daphnoides Sap.	....	....	....	....	+	....	....
demersum Sap.	....	....	....	....	+	....	....
dissectum Sap.	....	....	....	+	....	....	....
leucospermoides Sap.	....	....	....	+	....	....	....
oblongatum Sap.	....	....	....	....	+	....	....
oxyacanthæmorphum Sap.	....	....	....	+	....	....	....
truncatum Sap.	....	....	....	....	+	....	....
Protorhipis Choffati Sap.	....	+	....	....	....	....	....
Pteridoleimma phycomorpha Sap.	....	....	....	+	....	....	....
spoliatum Sap.	+	....	....	....	....	....	....
tripartitum Sap.	+	....	....	....	....	....	....
Ravenalospermum incertissimum Sap.	....	....	....	....	+	....	....
Rhizocaulon elongatum Sap.	+	+	....	....	....	....	....
vetus Sap.	+	....	....	....	....	....	+
Ruffordia Gœpperti (Dunk.) Seward	+	+	....	+	....	....	....

List of the Lower Cretaceous plants of Portugal with their geological distribution in that country--Continued.

Species.	Mesozoic.						
	Cretaceous.						
	Lower Cretaceous.						
	Neocomian.	Urgonian.	Aptian.	Albian.	Vraconnian.	Cenomanian.	Jurassic.
Salix assimilis Sap	....	....	....	....	+	....	....
infraeretacica Sap	....	....	....	+	....	....	....
retinenda Sap	....	....	....	+	....	....	....
Sapindophyllum brevior Sap	....	....	....	....	+	....	....
subapiculatum Sap	....	....	....	....	+	....	....
Sassafras protophyllum Sap	....	....	....	+	....	....	....
Scleropteris debilior Sap	+	....	....	....	....	....	....
Sequoia lusitanica Heer	+	....	+	....	....	+	....
subulata lusitanica Sap	....	....	....	+	....	....	....
Sphæria phylostichoides Sap	....	....	....	+	....	....	....
Sphenolepidium debile Heer	+	+	+	+	....	....	....
Kurrianum (Dunk.) Heer	+	+	+	+	+	+	....
Sternbergianum (Dunk.) Heer	+	+	+	+	+	....	....
Sphenopteris acutidens Sap	....	+	....	....	....	....	+
aneimiæformis Sap	....	+	....	....	....	....	....
angustiloba Heer	....	+	+	....	....	+	....
capillaris Sap	+	....	....	....	....	....	....
cercalensis Sap	....	+	....	....	....	....	....
Choffatiana infraeretacica Sap	+	....	....	....	....	....	....
Cordai (Dunk.) Schenk	....	+	....	....	....	....	....
crenularis Sap	....	....	....	+	....	....	....
cuneifida Sap	+	+	....	....	....	....	....
debiliformis Sap	+	....	....	....	....	....	....
debilior Sap	....	....	....	+	....	....	....
dissectifolia Sap	+	....	....	....	....	....	+
dissectiformis Sap	+	....	....	....	....	....	....
flabellina Sap	....	....	....	+	....	....	....
flabellinervia Sap	+	....	....	....	....	....	....
flabellisecta Sap	+	....	....	....	....	....	....
ginkgoides Sap	+	....	....	....	....	....	....
Gomesiana Heer	+	....	....	....	....	....	....
involvens Sap	....	....	....	+	....	....	....
linearisecta Sap	....	+	....	....	....	....	....
lobulifera Sap	+	+	....	....	....	....	....
lupulina Heer	+	....	....	....	....	....	....
plurinervia Heer	+	+	?	....	....	....	....
polyclada Sap	....	+	....	....	....	....	....
pseudo-Cordai Sap	....	....	....	+	....	....	....
pseudolepida Sap	+	....	....	....	....	....	....
pygmæa Sap	....	+	....	....	....	....	....
recurrens Sap	....	....	....	+	....	....	....
subtilinervis Sap	+	....	....	....	....	....	+
tenuifissa Sap	....	....	+	+	....	....	....
Stachypteris minuta Sap	+	....	....	....	....	....	+
Tænidium lusitanicum Heer	....	....	+	....	....	....	....
Thuyites debilis Sap	....	....	+	....	....	....	....
densior Sap	+	....	....	....	....	....	....
pulchelliformis Sap	+	....	+	....	....	....	+
Viburnum vetus Sap	....	....	....	....	+	....	....
Widdringtonites debilis Sap	+	....	....	....	....	....	+
pygmæus Sap	+	....	....	....	....	....	....
Williamsonia minima Sap	+	....	....	....	....	....	....
Yuccites fractifolius Sap	+	....	....	....	....	....	....

Table of distribution of the eleven species of fossil plants from other beds that occur in the Lower Cretaceous of Portugal.

Species.	Lower Cretaceous of Portugal.					Lower Cretaceous of America.						Purbeck of England.	Wealden.							Neocomian.		Urgonian.			Gault of Belgium.	Cenomanian.			Senonian of Blankenburg.	Rhetic of Bavaria.	Lias of Hungary.	Ipswich beds of Australia.	Oolite.		Coralian of France.	Kimmeridgian.		Upper Jurassic of Japan.
	Valanginian.	Urgonian.	Aptian.	Albian.	Yraconnian.	James River.	Rappahannock.	Mount Vernon.	Aquia Creek.	Potomac.	Trinity.	Kootanie.		England.	France.	Germany.	Austria.	Moravia.	Westphalia.	Russia.	Silesia.	Spitzbergen.	Greenland.		Portugal.	Saxony.	Bohemia.					Yorkshire.	Spitzbergen.		Portugal.	France.	
Baiera cretosa Schenk	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Cladophlebis Browniana (Dunk.) Sew	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Cladophlebis Dunkeri (Schimp.) Sew	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Egmisetites Burchardti Dunk	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Matonidium Goepperti (Ett.) Schenk	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Onychiopsis Mantelli (Brongn.) Sew	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Rufordia Goepperti (Dunk.) Sew	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Sphenolepidium Kurrianum (Dunk.) Heer	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Sphenolepidium Sternbergianum (Dunk.) Heer	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Sphenopteris Cordai (Dunk.) Schenk	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Stachypteris minuta Sap	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Table of distribution of twelve species of plants from the Lower Cretaceous of Portugal, and of the Potomac species to which they are related.

Portuguese species.	Lower Cretaceous of Portugal.				Lower Cretaceous of the United States.										Cenomanian.				Dakota Group.	Senonian.		Oolite.			Potomac species.
					Potomac.																				
	Valanginian.	Urgonian.	Albian.	Vraconnian.	James River.	Rappahannock.	Mount Vernon.	Aquia Creek.	Albirupean.	Raritan.	Island Series.	Kootanie.	Cape Lisburn.	Saxony.	Bohemia.	Moravia.	Greenland.		Germany.	Greenland.	Spitzbergen.	Siberia.	Persia.	
Aralia calomorpha Sap.			+							+				+	+	+		+						Aralia formosa Heer.
Cladophlebis fissipennis Sap.	+					+																		Asplenioptcris pinnatifida Font.
Cladophlebis subcycadina Sap.	+				+							+												Cladophlebis distans Font.
Dicotylophyllum corrugatum Sap.		+						+																Populophyllum reniforme Font.
						+	+	+																Proteæphyllum reniforme Font.
Eucalyptus Choffati Sap.				+						+	+			+	+	+	+	+						Eucalyptus Geinitzi Heer.
Podozamites ? acutus Sap.	+	+				+																		Nageiopsis ovata Font.
					+	+		+																zamioides Font.
					+																			Phyllocladus heterophylla Font.
Podozamites Henriquesi Sap.			+									+	+		+		+		+					Podozamites latipennis Heer.
												+												nervosus Newb.
Podozamites linearis Sap.	+									+								+				+	+	Podozamites angustifolius (Eichw.) Schimp.
Podozamites ovifermis Sap.	+					+																		Nageiopsis obtusifolia Font.

Table of distribution of twelve species of plants from the Lower Cretaceous of Portugal, and of the Potomac species to which they are related—Continued.

Portuguese species.	Lower Cretaceous of Portugal.				Lower Cretaceous of the United States.									Cenomanian.					Senonian.		Oolite.			Potomac species.
					Potomac.																			
	Valanginian.	Urgonian.	Albian.	Vraconnian.	James River.	Rappahannock.	Mount Vernon.	Aquia Creek.	Albirupean.	Raritan.	Island Series.	Kootanie.	Cape Lisburn.	Saxony.	Bohemia.	Moravia.	Greenland.	Dakota Group.	Germany.	Greenland.	Spitzbergen.	Siberia.	Persia.	
Salix assimilis Sap.				+																				
										+	+							+						Salix proteæfolia Lx.
Sassafras protophyllum Sap.			+																					
								+																Sassafras cretaceum heterolobum Font.
Sequoia subulata lusitanica Sap.			+																					
					+	+			+	+							+			+				Sequoia subulata Heer.

As will be seen from the first of these tables, the floras of the several horizons in the Lower Cretaceous of Portugal differ less in their abundance than those of the Jurassic. The largest is that of the Valanginian, amounting to 88 species, or over 43 per cent; the Urgonian has yielded only 45 species, or 22 per cent; the Aptian, 25 species, or over 12 per cent; the Lower Albian, 64 species, or nearly 32 per cent; the Upper Albian or Vraconnian, 26 species, or nearly 13 per cent. The striking coincidence of the parallelism between these horizons and those of the Potomac formation in America is still further heightened by the circumstance, accidental perhaps, that the numerical proportion existing between the species now known at the corresponding horizons in America is very nearly the same. The Basal Potomac, corresponding to the Valanginian, has yielded 329 species, or a little over 44 per cent; the Mount Vernon clays, which were compared with the Urgonian, 42 species, or somewhat less than 6 per cent; the Aquia Creek beds, corresponding to the Aptian, 137 species, or rather more than 18 per cent; the Raritan beds and their equivalents, compared to the Lower Albian, 264 species, or nearly 36 per cent; and the Island series, compared to the Vraconnian, 133 species, or 18 per cent. These results may be put in the following tabular form:

Comparative table of percentages.

Lower Cretaceous of Portugal.		Potomac formation of the United States.	
Horizons.	Per cent.	Horizons.	Per cent.
Vraconnian	13	Island series	18
Lower Albian	32	Amboy Clays, etc	36
Aptian	12	Aquia Creek series	18
Urgonian	22	Mount Vernon clays	6
Neocomian	43	Basal Potomac	44

The Mount Vernon clays have been very little developed as yet, and when this florula is thoroughly known it will probably fully equal that of the Urgonian beds of Portugal relatively to the total flora.

Taking the Cretaceous flora of Portugal as a whole, exclusive of the Cenomanian, it is found to consist of 2 algæ, 2 Hepaticæ, 1 species of Isoetes, 3 of Lycopodites, 2 equiseta, 79 ferns, 15 cycads, 29 conifers, 5 anomalous types classed by the author under the head of Proangiosperms, 16 monocotyledons, 47 dicotyledons, and 3 forms of uncertain affinity.

It will be seen that, as in the Jurassic, so in the Cretaceous, the ferns predominate, and of these 30 species belong to the genus Sphenopteris, and 12 to Cladophlebis. Seven of the cycads belong to the genus Podozamites, and 3 to Glossozamites. The conifers are much more evenly distributed, there being 5 species of Brachyphyllum, and 3 each of Sphenolepidium and Thuyites, while a large number of genera have

only one or two species. Among these are Frenelopsis, Palæocyparis, Palæolepis, Sequoia, and Widdringtonites. The genera referred to the Proangiosperms are Changarniera, Eolirion, Yuccites, Delgadopsis, and Protorhipis, some of which will require special mention further on. Nine of the monocotyledons consist of grass-like objects referred to Poacites, some of which Saporta classes under the Proangiosperms and others as true monocotyledons, but I prefer to group them together. The dicotyledonous flora is here well developed, but most of the forms occur in the Albian. Seven species are referred to a new genus, Proteophyllum, a name too near to both Proteæphyllum of Fontaine and Protophyllum of Lesquereux, but the forms are different from both of these; four to the new genus Dicotylophyllum, and 3 each to Eucalyptus, Laurus, and Salix.

In comparing the Cretaceous flora of Portugal with that of America it is true that we find only a few species that are common to the two countries, really only five, as follows:

Cladophlebis Browniana (Dunk.) Seward.
Cladophlebis Dunkeri (Schimp.) Seward.
Onychiopsis Mantelli (Brongn.) Seward.
Sphenolepidium Kurrianum (Dunk.) Heer.
Sphenolepidium Sternbergianum (Dunk.) Heer.

These are all plants of wide distribution, and argue very little for the identity of the particular horizons in which they occur. The comparisons which are indicated in the third of the above tables are much more significant from this point of view, and it is altogether probable that if all the material from both countries could be studied together there would be a large number of specific identifications.

We should not, of course, expect the species to be common to any great extent, and the comparison is practically limited to the genera. Looked at from this point of view, we see that the resemblance is indeed close, a great number of the important genera occurring in both floras. There are no less than 46 of these common to the two, though in some cases the author's individuality is probably alone responsible for slight differences of termination in the names. For example, forms referred to Baiera by one would be referred to Baieropsis by the other, and so with Ctenis and Ctenidium, Myrsine and Myrsinophyllum, Oleandra and Oleandridium, Salix and Saliciphyllum, Thuya and Thuyites, etc.

Many of these genera, when we consider the difference in the size of the two floras (about as 1 to 4), occur in both countries in nearly the same proportion. For example, of Aralia we have in Portugal 2 species, in America 11; of Brachyphyllum, in Portugal 5, in America 9; of Cladophlebis, in Portugal 12, in America 25; of Frenelopsis, in Portugal 2, in America 6; of Laurus, in Portugal 3, in America 8; of Myrica, in Portugal 2, in America 11; of Podozamites, in Portugal 7, in America 15; of Sphenolepidium, in Portugal 3, in America 9, etc. There are, of course, some cases in which the proportion is not the same. Thus, only 1 species of Magnolia occurs in the Portuguese beds, while in America we

have 12, and on the other hand the largest Portuguese genus, Sphenopteris, represented there by 30 species, counts in America only 8 species. But here it may be supposed that the true representative in America of the Sphenopteris type of Portugal is really that exceedingly abundant genus Thyrsopteris, which numbers 40 species in the American beds. This would somewhat restore the relative proportions. On the whole, then, it may be considered that the Lower Cretaceous flora of Portugal is, botanically speaking, a very close repetition of that of America; and in view of the fact that in both countries a number of distinct horizons showing the progressive change in the flora throughout that period have yielded fossil plants in such a way that, if the Portuguese beds were as fully developed as are the American ones, each of these florules might also be compared, the subject becomes rather fascinating.

ARCHETYPAL ANGIOSPERMS.

Space will only permit the consideration of one other important aspect, viz, a comparison of the dicotyledonous forms in the two countries together with those ancestral types which Saporta regards as prophetic of that great group of plants. This last question may be considered first. He finds among the specimens certain forms which he refers to the genus Protorhipis of Andræ. This genus was founded in 1853 upon some remarkable forms from the Lias of Steierdorf in Banat, Hungary,[1] which Andræ regarded as a fern and placed under the Pecopterideæ. He compares it with Jeanpaulia, which has since been proved identical with Baiera and correctly referred to the Coniferæ; also to Cyclopteris, Comptopteris, Diplodictyum, and Thaumatopteris, among fossils, and to Platycerium, among living ferns.

When I first saw the figure of his *Protorhipis Buchii*, I had grave doubts of its being a fern and inclined to believe that it represented some higher type of vegetation. I am therefore not surprised that Saporta has arrived at the same conclusion, and am highly gratified that he has had the courage to give it publicity, notwithstanding the fact that Schimper, Schenk, Heer, and Nathorst have all been content to regard it as a fern of the type of Drynaria, Platycerium, Allosorus, Clathropteris, and the other living and fossil forms already mentioned. I have reproduced Andræ's figure (Pl. CVI, Fig. 1) for purposes of comparison.

In 1865 Zigno discovered another species which, however, differs in a marked manner from the original of Andræ, having the margins entire. It is a small, deeply kidney-shaped leaf resembling that of some species of Asarum, and was named *P. asarifolia*. This comes from the Oolite of Italy.[2]

The forms described by Nathorst in 1878,[3] though much smaller, are

[1] Lias-Flora von Steierdorf im Banate, by K. J. Andræ, Abhandl. d. k. k. geol. Reichsanst., Vol. II, Abth. 3, No. 4, 1853, pp. 35–36, pl. viii, fig. 1.

[2] Fl. Foss. Form. Oolithicæ, Vol. I, 1865, p. 180, pl. lx, figs. 2, 2*a*.

[3] Fl. v. Bjuf, Pt. 1, p. 42; Pt. 2, p. 57, pl. xi, figs. 2, 4.

otherwise similar to *P. Buchii*, and Nathorst at first proposed to refer one of them to that species, but later concluded that it was distinct and made two species, *P. integrifolia* and *P. crenata*.

In 1880 Heer described another small cordate form from the Oolite of Siberia. It is similar to Zigno's species and was named *P. reniformis*.[1] Two years later, however, he found another similar form in the Kome beds of Greenland, Urgonian, which is rather cordate than reniform and which he called *P. cordata*.[2] Both these forms have the margins entire.

Saporta in this work has revised all these forms and comes to the conclusion that they can not be ferns, and although the original *P. Buchii* and both of Nathorst's species, though lacking the distinction of midrib and secondary nerves, so closely resemble dicotyledonous leaves and are somewhat comparable in nervation to Credneria and some fossil Viburnums, as well as to such living genera as Glechoma and Chrysosplenium, still he hesitates to class them in that group. He has carefully refigured both of Nathorst's specimens, and these revised figures are here reproduced (Pl. CVI, Figs. 4 and 5). All these he carefully compares with the Portuguese form, which he names *P. Choffati*, two of the most perfect figures of which are here shown (Pl. CVI, Figs. 2 and 3), and classes the whole in the special group which he long ago created and denominated the Proangiosperms, as representing the forerunners of both the monocotyledons and dicotyledons. The Portuguese species comes from the beds at Cercal, which, as we have seen, may be referred to the Urgonian. It is therefore probably of about the same age as the Kome beds of Greenland from which Heer derives one of his species; all the others, of course, are of far more ancient origin, viz, Jurassic, and it is not to be wondered at that no one should have ventured to refer them to any modern type.

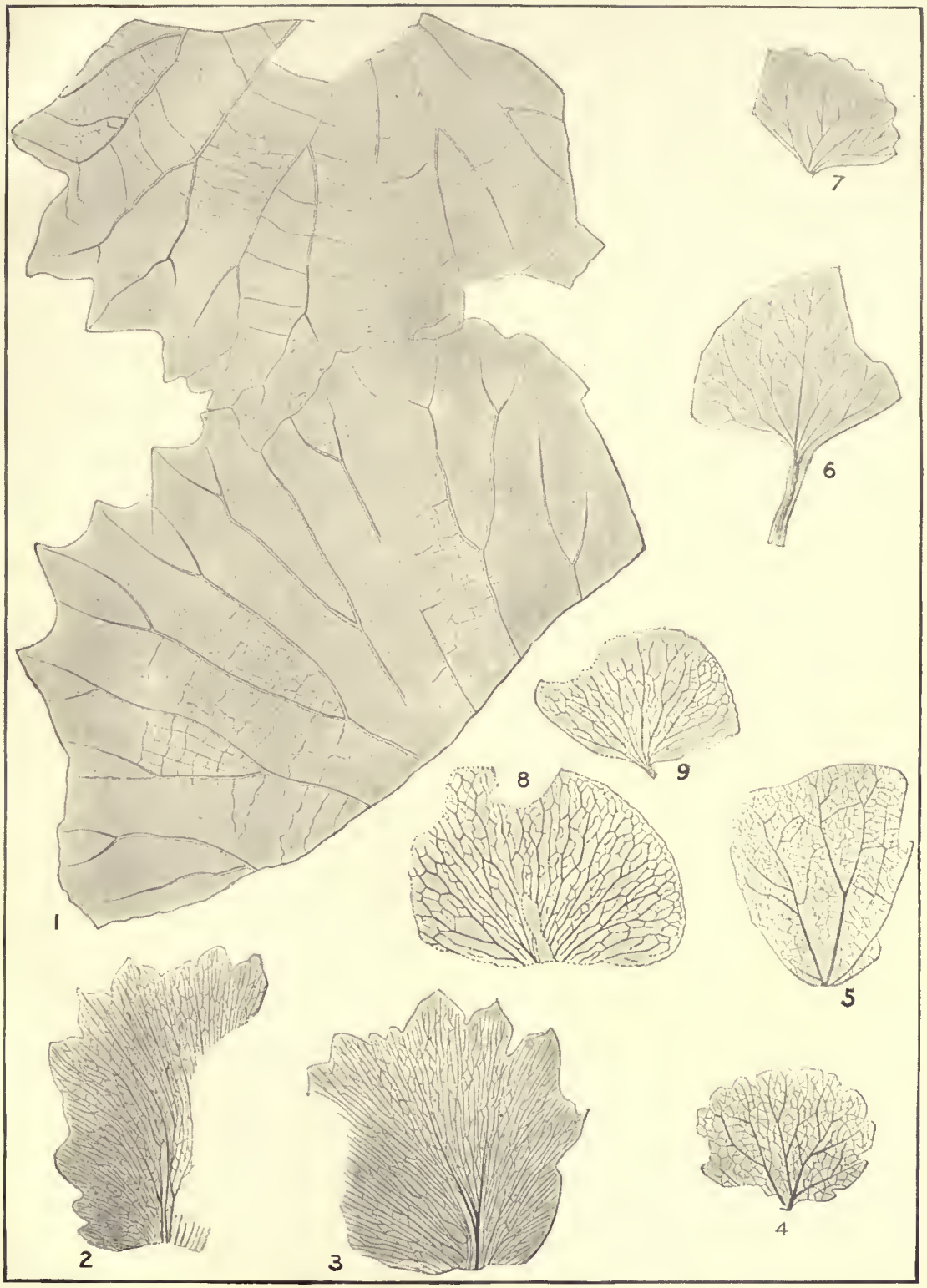
Of the other four genera referred to this group, viz, Changarniera, Yuccites, Delgadopsis, and Eolirion, the first two come from the Valanginian (Neocomian) of S. Sebastião, the third from the Urgonian of Cercal, and the last from the Albian of Buarcos. They all seem to be ancestral monocotyledons. Delgadopsis occurs in two forms, first as a sort of culm or broad striate stem, and secondly in the form of a jointed rhizome, the swollen joints emitting innumerable rootlets, which when absent leave peculiar scars.

Choffatia Francheti from Cercal, regarded by the author as a dicotyledon, is also a very remarkable plant, and has been aptly compared by him to certain euphorbiaceous forms, such as Phyllanthus. It also resembles some species of Euphorbia. It seems to be a floating aquatic, and specimens with the fibrous roots occur in the collection. In some of these, descending fibers occupy one side of the stem or rachis, while the floating or aerial leaves occupy the other.

[1] Fl. Foss. Arct., Vol. VI, Abth. 1, Pt. 1, p. 8, pl. i, fig. 4*a*.
[2] Ibid., Abth. 2, p. 10, pl. iii, fig. 11.

PLATE CVI.

PLATE CVI.



ARCHETYPAL ANGIOSPERMS FROM THE MESOZOIC OF EUROPE AND AMERICA.

Upon the whole it can not be said that any of these higher types, found below the Albian and corresponding in age to our Middle and Older Potomac, very closely resemble the plants of the same general class from the American beds of that age, and yet there are certain Potomac forms referred by Professor Fontaine to Menispermites, Hederæphyllum, Proteæphyllum, and Populophyllum, whose areolate nervation somewhat resembles that of *Protorhipis Choffati*. The new genus Dicotylophyllum, of which he finds four species in the Urgonian of Cercal, and which he very properly regards as a true dicotyledon, somewhat resembles the Protorhipis, but lacks the peculiar areolate nervation. These leaves are all quite small, but show a somewhat distinct midrib and usually 2 to 4 lateral primaries. In form they recall some species of Vitis or Cissites, and *D. cerciforme*, while not resembling Cercis, as the specific name would imply, has many of the characteristics of Hedera. It may be roughly compared with Professor Fontaine's Vitiphyllum, from the Potomac of Baltimore, and except in size *D. hederaceum* and *D. corrugatum* are fairly comparable with *Populophyllum reniforme* Font. and *Proteæphyllum reniforme* Font. Several of the American forms are reproduced here for comparison (see Pl. CVI, Figs. 6–9).

In the Albian beds of Buarcos, and especially in the Vraconnian of Nazareth, we begin to find some of the higher types. But the genus Proteophyllum has still a very ancient appearance, with a more or less areolate nervation. It is a narrowly-lobed leaf, remotely recalling in its general form some species of Dewalquea. It may be possible to trace this form into his *Aralia calomorpha* from the same beds. His *Adoxa prœatavia* is a very peculiar plant, which also reminds one of Vitiphyllum Font., although species of the latter genus which show the branching character have not yet been figured. His *Braseniopsis venulosa* has some of the characteristics of Protophyllum of Lesquereux, but is usually smaller and always entire; the nervation is also different except at the base of the leaf, which has a large expansion below the summit of the petiole, as in Protophyllum. *Myrsinophyllum revisendum* will doubtless have to be revised. It is much like Potomac forms that have been referred to Myrica (e. g., *M. brookensis*) and Celastrophyllum. It is entirely different from the *Myrsine borealis* of Heer, which, with two other species, occur in the Amboy Clays and Tuscaloosa formation. His *Cissites obtusilobus*, of which I give one figure (Pl. CVII, Fig. 1), is very close to Fontaine's *Vitiphyllum* (*Cissites*) *multifidum* (Pl. CVII, Figs. 2–5). His *Menispermites cercidifolius*, though much smaller, is not unlike Professor Fontaine's *M. virginiensis*, especially the smaller forms which I have found in the Mount Vernon clays. His *Aralia proxima* can scarcely be distinguished from *A. Wellingtoniana* of the Dakota group, more common in the Newer Potomac.

It is only in the Nazareth beds (Vraconnian) that we find the typical Amboy Clay flora. Here we have the Eucalyptus, Laurus (Laurophyllum), Salix, Myrsinophyllum, Sapindophyllum, etc., some of which are doubtless specifically identical with forms described by Newberry, and

it is altogether probable that if the posthumous work of Dr. Newberry, now in press, had been in the hands of the author a large number of the species would have been identified with American forms.

I will notice only one other significant fact. In the Cenomanian beds which overlie these last, as it would seem unconformably, but which may not be so widely separated from them as has been supposed, there occurs a large elongated leaf which the Marquis has called *Chondrophyton laccratum*. It agrees only in its finer nervation with *C. dissectum* Sap. & Mar., the only other species.[1] It has a very delicate nervation with small polygonal meshes, and an entire paryphodrome margin, but the remarkable fact is that it seems to have a deeply retuse summit. It is evident that from the specimen the author was unable to make this latter out with certainty; but he has drawn the marginal lines so as distinctly to indicate it. So desirous was he that this leaf should be correctly represented that he has given us two interpretations from drawings made at different times (figs. 4 and 5 of pl. xxxviii). He states that he considers fig. 5 to represent the form better than fig 4, and it is in this that the terminal lobation is most clearly shown. A comparison of this figure with the numerous specimens of *Liriodendropsis simplex* of Newberry, leaves no doubt whatever that the Portuguese plant is at least a congener of the American plant, and it is just possible that it may belong to the same species. As this form has been three times published,[2] it is a little surprising that Saporta did not think to compare it with the Portuguese plant. There are differences in the finer nervation, but this is also perceptible between his two drawings of the same specimen; these also differ in different specimens of the American plant, and one or two other species remain to be published. When all the material is illustrated most of these differences will disappear. If any remain they can be ascribed to difference of age and geographical position. I do not, therefore, hesitate to refer this plant to the American genus and to rename it *Liriodendropsis laccrata*. On Pl. CVII, Fig. 6, Saporta's best figure is here reproduced, by the side of which (Figs. 7 and 8 of the same plate) is shown our *L. simplex* from the Amboy Clays. I had expected to use some of the published figures above referred to, but thinking that possibly Dr. Hollick might have some drawings that would be available for the purpose I sent him Saporta's plate and requested him to inform me whether he knew of any specimens of Liriodendropsis that approached any more closely to the Portuguese plant than those already published. He investigated the matter and made drawings of two forms, both of which deviate slightly from the type of *L. simplex*. That represented by Fig. 7 seems to be nearest to Saporta's figure. It is what Dr. Newberry distinguished as the variety *angustifolia*. The other form, Fig. 8, is nearer the type, but belongs near a group that Dr. Hollick proposes to regard as forming the variety *constricta*. It shows the summit better than the other.

[1] L'Évolution du Règne Végétal. Les Phanérogames, par G. de Saporta et A. F. Marion, Vol. II, Paris, 1885, p. 120, fig. 126.

[2] Bull. Torr. Bot. Club, Vol. XIV, New York, January, 1887, p. 6, pl. lxii, figs. 2, 3, 4; Am. Journ. Sci., 3d ser., Vol. XXXIX, New Haven, February, 1890, p. 98, pl. ii, figs. 6, 7; Trans. N. Y. Acad. Sci., Vol. XI, 1892, p. 102, pl. ii, figs. 2–7, 9.

PLATE CVII.

PLATE CVII.

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DICOTYLEDONS FROM THE CRETACEOUS OF PORTUGAL AND THE UNITED STATES.